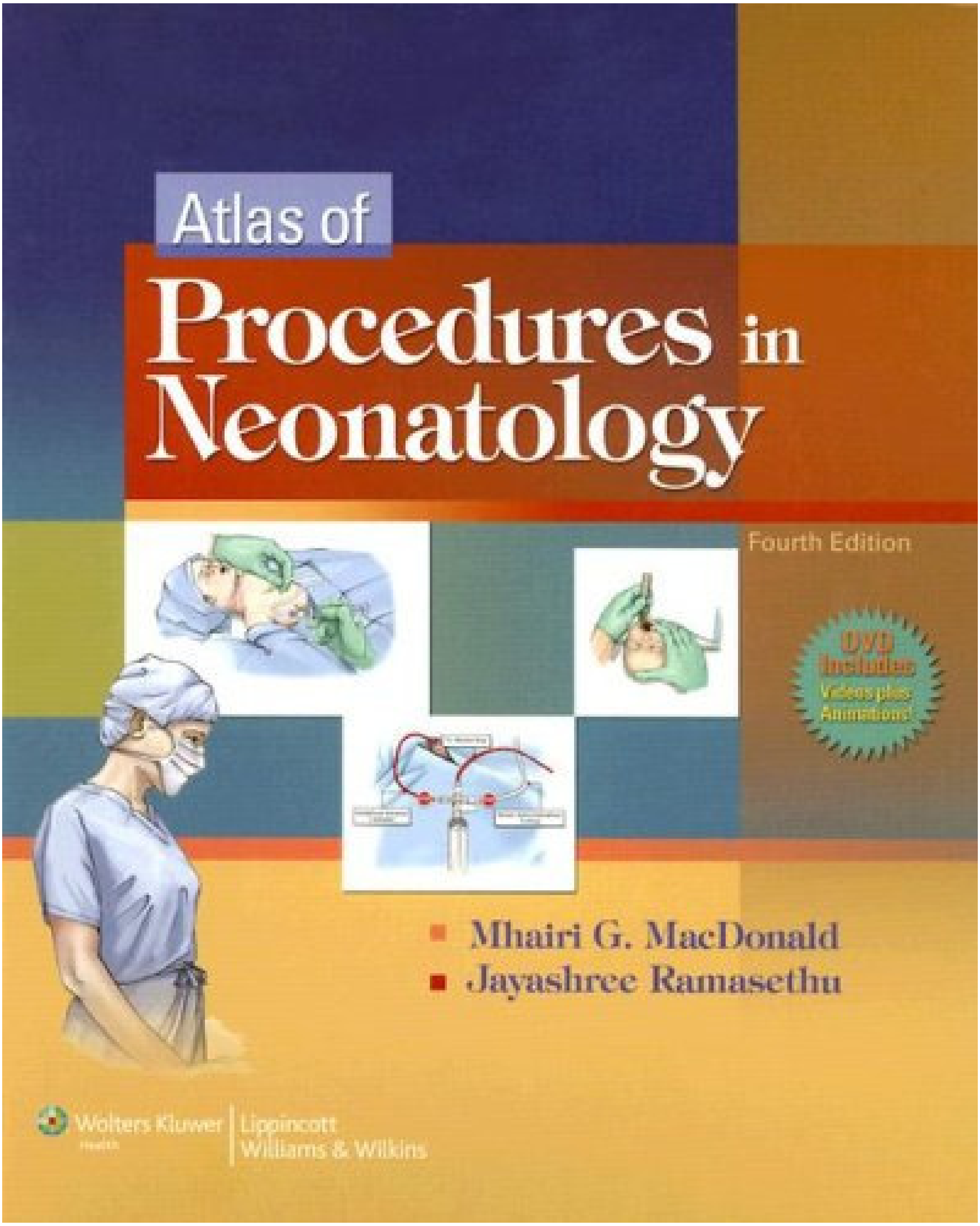

Atlas of Procedures in Neonatology

Fourth Edition

DVD Includes
Videos plus Animations!

Mhairi G. MacDonald
Jayashree Ramasethu

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Dedication

â€œThis book is dedicated to my mother, Jane Graham MacDonald, for her steadfast support, love, and encouragement.â€□

Mhairi G. MacDonald MBChB,FRCPE,FRCPCH,DCH

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Preface

It has been over a quarter of a century since the first edition of the Atlas of Procedures in Neonatology was published. The basic philosophy and purpose of the Atlas, as reflected in the preface to editions one through three, has not changed as the field of neonatal-perinatal medicine has matured.

This fourth edition has undergone a significant facelift, and the majority of illustrations are now in color. Color photographs of procedure complications proved comparatively difficult to obtain; it is tempting to hope that this reflects a decline in their incidence. The new, fold-over cover continues to allow the book to open flat and also offers easy identification on a bookshelf.

In the preface of the third edition, we noted that some promising technologies, such as transcutaneous bilirubin measurement, required further field testing. A chapter on transcutaneous bilirubin measurement has been added in this edition, plus one on auditory screening, and three other new chapters.

With the exception of Aseptic Preparation, the procedures included on the DVD fall into two categories:

- Commonly performed procedures, such as peripheral and umbilical line placement and endotracheal intubation.

- Vital emergency procedures that trainees may have infrequent opportunity to perform, such as chest aspiration/placement of a thoracostomy tube, or rare opportunity to perform, such as exchange transfusion.

Particularly in the case of exchange transfusion, there is now a generation of neonatologists who have graduated from training with limited practical experience of the procedure but who now have the responsibility to teach it to trainees. We hope that the videoâ€”animation will prove a valuable teaching resource.

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Preface to the Third Edition

Almost two decades have passed since the publication of the first edition of Atlas of Procedures in Neonatology. We have seen our patients become progressively smaller, less mature, and more susceptible to iatrogenic morbidity. The increasing fragility of our patient population and the escalating complexity of care continue to make neonatology challenging. These challenges have necessitated not only innovations in technology and equipment but also increased familiarity with and proficiency in procedures.

This revised edition of Atlas of Procedures in Neonatology reflects changes that have come about in the management of neonates since the second edition was published in 1993. Reliable monitoring techniques and therapeutic modalities have been developed or refined since then for some aspects of care; however, other promising technologies, such as noninvasive transcutaneous bilirubin monitoring, require additional field testing and validation.

The passing of the era of the mercury thermometer deserves special note. The prototype of the widely used clinical mercury thermometer was designed over 130 years ago, an admirable track record for a medical device. Technical advances in thermometry have rendered the risk of mercury toxicity from broken thermometers unacceptable. As a result, in July 2001, the Committee on Environmental Health of the American Academy of Pediatrics recommended that mercury thermometers no longer be used for pediatric patients.

Advances in the prevention and intrauterine management of alloimmune hemolytic disease, along with the liberal use of phototherapy, have resulted in a significant decrease in the need for postnatal exchange transfusionsâ€”to the point that fellows in neonatalâ€“perinatal medicine now occasionally complete training programs without ever performing the procedure. The reappearance of kernicterus in well full-term neonates underscores the importance of retaining the chapter on exchange transfusions in this edition.

Cryotherapy for retinopathy of prematurity has been replaced by laser therapy. A chapter on ostomy care has been added. Expanded chapters on the management of extravasation injuries and vascular spasm and thrombosis are acknowledgments of the all-too-common iatrogenic problems in neonatal intensive care. A new chapter on perimortem sampling provides guidelines for testing in the event of sudden or unexpected death.

Updated information regarding the complications of each procedure is provided to facilitate risk-versus-benefit considerations and the informed consent process. Complications are listed whenever possible in order of frequency of occurrence or of importance.

At the request of those who used the previous editions of Atlas of Procedures in Neonatology, we have modified the binding to allow the book to lie flat when open. As in previous editions, commercial products listed in the text are intended for illustrative purposes only; no endorsement is implied. Commercial availability of some equipment may change subsequent to the publication of this edition.

Acknowledgment of the fact that invasive procedures are currently unavoidable in the care of sick neonates must come with the recognition that there is responsibility to reduce potential iatrogenic morbidity to the minimum possible. The latter may be achieved by strict adherence to basic principles of asepsis, careful monitoring and maintenance of patient homeostasis, and by ensuring that procedures are performed or supervised by those with the requisite expertise.

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Preface to the Second Edition

There is nothing more gratifying to editors than to see their book lying open and dog-eared during a bedside visit to another facility. We have been pleased to find the first edition of the Atlas of Procedures in Neonatology used not only by trainees and staff in neonatology but also by other members of the neonatalâ€“perinatal health care team, including radiologists and respiratory therapists.

The primary purpose of the Atlas is to provide a detailed, step-by-step approach to procedures, most of which are performed by neonatologists, pediatricians, and nurses within the nursery. Some proceduresâ€”such as extracorporeal membrane oxygenation cannulation, operative tracheotomy, gastrostomy, and cryotherapyâ€”are usually performed by surgical specialists but are included to promote understanding by those who are responsible for the perioperative care of the neonate.

On the advice of our readers, we have selected a binding that will allow the book to open flat so as to facilitate bedside use during procedures. The organizational format of the first edition remains. We recommend studying an entire procedure before starting it, not only to review the technique but also to better weigh benefits against risks by understanding the complications and precautions. As in the first edition, we have emphasized the anatomical differences between the neonate and older patients that influence the performance of certain procedures. After every procedure, we have attempted to include a comprehensive list of complications in order to heighten awareness of their potential impact on both morbidity and mortality. The order of listing does not necessarily reflect the frequency or severity of any single complication.

It is sobering to observe that a significant number of complications, some of them not previously recognized, continue to be reported for procedures that have been standard in neonatal nurseries for more than two decades. For example, since the first edition of the Atlas was published, reports in the literature on complications of umbilical artery catheterization have approximately tripled. With every new procedure there is a learning curve, but one would expect the incidence of complications to decrease as experience and expertise increase. Clearly, the number of reported complications does not represent their true incidence. An optimistic view might be that increased reporting of complications reflects a more universal respect for the possibility of their occurrence and attempts to find ways of preventing or minimizing them.

When any procedure is applied to smaller and more immature infants, it is not only technically more difficult but also more likely to be accompanied by side effects or complications. For all procedures performed in the newborn there is a baseline morbidity; no procedure will be absent complications. For example, placement of a peripheral intravenous line is a basic procedure essential for the survival of sick newborn babies. There have been significant improvements in the size and quality of i.v. cannulas and pumps specifically to allow for pressure obstruction alarms, low flow rates, and so forth. However, no matter how good the care of the infant and the i.v., there will always be incidents of infiltration and chemical skin burns. It behooves each clinician to carefully weigh the risks versus the benefits of every procedure before beginning it, while any piece of equipment remains in place, and even in the months and years after completion.

One cannot possibly practice good medicine and not understand the fundamentals underlying therapy. Few if any rules for therapy are more than 90% correct. If one does not understand the fundamentals, one does

more harm in the 10% of instances to which the rules do not apply than one does good in the 90% to which they do apply.
â€”Fuller Albright

Mary Ann Fletcher MD
Mhairi G. MacDonald MBChB, FRCP(E), DCH

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Preface to the First Edition

The rapid advances in neonatology in the last 15 years have brought with them a welter of special procedures. The tiny, premature, and the critically ill term neonate is attached to a tangle of intravenous lines, tubes, and monitoring leads. As a result, more and more procedures are done at the bedside in the intensive-care nursery, rather than in a procedure room or operating room. With these technical advances has come the opportunity for more vigorous physiologic support and monitoring. With them also has come a whole new gamut of side-effects and complications. The old dictum to leave the fragile premature undisturbed is largely ignored. It is therefore the responsibility of those who care for sick newborns to understand the complications as well as the benefits of new procedures and to make systematic observations of their impact on both morbidity and mortality. Unfortunately, the literature on outcome and complications of procedures is widely scattered and difficult to access. Manuals that give directions for neonatal procedures are generally deficient in illustrations giving anatomic detail and are often cursory.

We are offering Atlas of Procedures in Neonatology to meet some of these needs. A step-by-step, practical approach is taken, with telegraphic prose and outline form. Drawings and photographs are used to illustrate anatomic landmarks and details of the procedures. In several instances, more than one alternative procedure is presented. Discussion of controversial points is included, and copious literature citations are provided to lead the interested reader to source material. A uniform order of presentation has been adhered to wherever appropriate. Thus, most chapters include indications, contraindications, precautions, equipment, technique, and complications, in that order.

The scope of procedures covered includes nearly all those that can be performed at the bedside in an intensive-care nursery. Some are within the traditional province of the neonatologist or even the pediatric house officer. Others, such as gastrostomy and tracheostomy, require skills of a qualified surgeon. Responsibility for procedures such as placement of chest tubes and performance of vascular cutdowns will vary from nursery to nursery. However, some details of surgical technique are supplied for even the most invasive procedures to promote their understanding by those who are responsible for sick neonates. We hope this will help neonatologists to be more knowledgeable partners in caring for babies and will not be interpreted as a license to perform procedures by those who are not adequately qualified.

The book is organized into major parts (e.g., â€œVascular Access,â€ â€œTube Placement,â€ â€œRespiratory Careâ€), each of which contains several chapters. Most chapters are relatively self-contained and can be referred to when approaching a particular task. However, Part I, â€œPreparation and Support,â€ is basic to all procedures. Occasional cross referencing has been used to avoid repetitions of the same text material. References appear at the end of each part.

Many persons have contributed to the preparation of this atlas, and we are grateful to them all. Some are listed under Acknowledgments, and others have contributed anonymously out of their generosity and good will. Special thanks is due to Bill Burgower, who first thought of making such an atlas and who has been gracious in his support throughout this project.

If this atlas proves useful to some who care for sick newborns, our efforts will have been well repaid. Neonatology is a taxing field: strenuous, demanding, confusing, heartbreaking, rewarding, stimulating, scientific, personal, philosophical, cooperative, logical, illogical, and always changing. The procedures described in this atlas will eventually be replaced by others, hopefully more effective and less noxious. In the meantime, perhaps the care of some babies will be assisted.

Mary Ann Fletcher MD
Mhairi G. MacDonald MBChB, FRCP(E), DCH
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1-Informed Consent for Procedures on Neonates

Harold M. Ginzburg

A. General Comments

Medicine is an art and a science needed by most, feared by some, and observed by all. Modern medical care in hospitals is generally provided by â€œteamsâ€□ of medical personnel including but not limited to physicians, nurses, therapists, and technicians (e.g., extracorporeal membrane oxygenation, respiratory therapy, dialysis) (1,2 and 3). By medical tradition, the physician and the hospital have been held responsible for the actions of the team members. Today, each team member is also medically and legally responsible for his or her own actions.

It is the fundamental duty and responsibility of those who provide medical care and treatment to neonates to inform the parent or guardian appropriately and to document that relevant information has been provided, and understood, and that informed consent has been obtained. Failure to obtain fully informed consent may result in legal liability for the health care provider under either a claim of negligence or a claim of assault and battery (depending on state law) (4,5,6,7).

Neonatologists, obstetricians, and pediatricians practice in a particularly emotionally charged area of medicine. Families are more ready to accept mortality and morbidity in their senior members than in their youngest members. Options for treatment must be carefully explained and include the option, when appropriate, of no treatment. Options for treatment should be presented in terms of the immediate, intermediate, and long-term effects of the treatment on the neonate and on those who will be directly affected by the medical decisions.

The federal government and the individual states and territories have laws, regulations, guidelines, policies, and practices that directly and indirectly affect the practice of medicine care (8,9). Federal and state reimbursement, licensure, inspection, and enforcement functions vary and may even be in conflict with each other. Therefore, health care providers are encouraged to consult with hospital administrative personnel and legal counsel when potential legal issues arise because, in the final analysis, â€œThe law does not permit [a health care provider] to substitute his own judgment for that of the patient [or guardian] (10).â€□

B. Medical Legal Concepts

- Duty
    - Legal: A duty is a legal and ethical responsibility. A breach (violation) of a duty owed to another person may result in legal liability. Duties are a reflection of the moral fiber of a community; they are codified in state and federal statutes and regulations. Public policies and laws thus become the vehicle for expressing a community's moral imperatives.
    - Medical: A health care provider has a duty to conform his or her practice to a reasonable (or, in some instances, usual) standard of care specific to the type of illness and to the particular circumstances in which the care and/or treatment are being provided. This duty includes performing only procedures for which, under normal circumstances, appropriate equipment and support are available and that he or she possesses the competence to perform.
- Health care providerâ€“patient relationship
    - Fiduciary (â€œpertaining to or involving one who holds something in trust for anotherâ€□): Health care providers and hospital care systems have a fiduciary duty to patients and their parents or guardians. A fiduciary duty is a responsibility that arises from the trust and confidence placed by the patient/parent/guardian in the health care professional. Health care providers are assumed to have superior medical knowledge; they are expected to warn their patients and to attempt to protect them from untoward or predictable harm. The fiduciary relationship is created when a health care provider responds to an expressed or implied request for treatment by the patient, his or her guardian, or a third party (e.g., emergency medical service personnel); the health care provider then has a duty to share his or her

knowledge about the nature of the illness, its prognosis, treatment options, and associated risks (these are the essential elements of an informed consent agreement). The health care provider also has a duty to protect patient information from access by those who do not have a legal right to access it.

  - Contract: The health care providerâ€“patient relationship is a contract. A health care provider and a patient (or his or her parent or guardian) enter into the contract, either implied or expressed, either verbally or written, for the performance of medical services. The contract created is based on the fiduciary relationship and not on a financial one.
- Standard of care
  - Legal: The health care provider has a duty to conform his or her practice to a reasonable standard of care in the particular type of case and in the particular circumstances in which the care and treatment are being provided.
  - Medical: The health care provider must not undertake any procedure that will place the patient at an unreasonably great risk of harm when weighed against the potential benefits. The health care provider must consider the consequences of his or her actions, or inactions, and exercise his or her best judgment when providing care.
- Negligence
  - General negligence: Negligence is the failure to do something that a reasonable man or woman, guided by those considerations that ordinarily regulate the conduct of human affairs, would do or the doing of something that a prudent and reasonable man or woman would not do.
  - Medical negligence: Medical negligence, or medical malpractice, is a special instance of negligence. A missed operative diagnosis, a therapeutic misadventure, a failure to arrange for follow-up care, and a failure to inform, warn, or protect the patient, or in some instances a third party, may be special instances of medical negligence. The medical care profession is held to a specific minimum level of performance based on the possession, or claim of possession, of â€œspecial knowledge or skillsâ€□ that have accrued through specialized education and training. A health care provider may be sued successfully only if there was a violation of a duty or obligation, recognized by law, that required the defendant-health care provider to conform to a particular standard of conduct in order to protect others, usually the patient, against unreasonable risks of harm.
- Informed consent
  - Clinical: Informed consent is educated consent; it is a cornerstone in the provision of medical care (11). Fundamentally, informed consent is a contract between the physician and the patient and/or the parent or guardian. Informed consent requires that sound, reasonable, comprehensible, and relevant information be provided by a health care professional to a competent individual (patient and/or their parent(s) or guardian) for the purpose of eliciting a voluntary and educated decision about the advisability of permitting one course of clinical action as opposed to another (12). Thus, informed consent involves (a) a clearly stated, understandable offer by the health care provider to provide services and (b) acceptance of the services by the patient or the surrogate; it is also (a) an offer, by the patient or the surrogate, to pay for the services or at least to acknowledge that they have a worth, and (b) it is the health care provider's acceptance of the payment or acknowledgment (13). Informed consent should also prevent unrealistic expectations from evolving, because all parties are made aware of the possibility of the failure of the proposed treatment plan.

    Informed consent implies that not only the treating physician, but all those who are involved in the patient's care (e.g., nurse practitioners, nurses, respiratory therapists) have a responsibility to use sound judgment and provide quality care (14). To create a valid contract, there is a legal requirement that an individual providing consent be legally competent and have the legal capacity or ability to enter into that contract (15). Health care providers treating children are sometimes faced with emotionally immature, incoherent, uncooperative, absent, or intoxicated parents. In such instances, assistance from the hospital attorneys and the courts may be required.

  - Research: The Declaration of Helsinki, agreed to by the World Medical Association in 1964, distinguished between â€œclinical research combined with professional careâ€□ (i.e., research that might directly benefit the patient) and â€œnontherapeutic clinical research (16).â€□ Special and specific informed consent needs to be obtained for procedures conducted as part of research studies unless the procedures are considered to be a component of the â€œroutine medical careâ€□ (see next section). The U.S. Department of Health and Human Services (HHS) (17) and the U.S. Food and Drug Administration (FDA) (18) have promulgated a series of regulations to ensure that research subjects, especially children, are adequately protected when they are enrolled in clinical trials or other clinical experiments. HHS has the power to investigate and sanction investigators for violating its regulations (19).

C. Obtaining Informed Consent

- The person obtaining consent should be aware that there are two levels of informed consent.
  - General informed consent (often referred to as a â€œblanket consentâ€□): The parent or guardian must understand that admission to a hospital entails active clinical intervention by a number of health care providers. While the parent or guardian can expect explanations of many of the procedures that will be used to help his or her child or ward, he or she cannot expect to be informed about every intervention. Routine medical care is considered to be covered under a general informed consent; each time blood is drawn or a nonexperimental medication is administered, a specific informed consent is not required. Each medical facility needs to define (within the limits of what is reasonable for the type of care provided as well as what is reasonable given the social context of the community) the components of routine care. For instance, in an intensive care nursery, placing an arterial line in a critically ill infant for the purpose of obtaining blood gases is not a unique procedure requiring a specific informed consent, whereas placing a neonate on extracorporeal membrane oxygenation would generally require specific informed consent. It is the procedures in the â€œgrayâ€□ area that require definition by the facility and individual unit as standard or otherwise. Both a lumbar puncture and the percutaneous placement of a central venous catheter may be considered standard routine procedures in a critical care unit. However, on a general pediatric ward, the percutaneous placement of a central close-up venous line might require specific informed consent.
  - Specific informed consent: The parent or guardian must recognize that beyond the routine medical care provided in a neonatal intensive care unit (NICU), there are specialized medical and surgical procedures that require that they be provided with specific additional information. This information will assist them in determining whether they should consent to the recommended procedure(s) on behalf of their infant. For each such procedure, a written description or an oral description documented in the patient's chart, describing the procedure and the risks and benefits of performing the procedure versus another procedure versus not performing the procedure should be provided.
- The person obtaining the informed consent should understand the following general concepts.
  - Coercion or undue influence: The health care provider has a duty to ensure that the parent or guardian voluntarily assents to permit the treatment or clinical research. Implied threats (such as the unintended impression that the quality of the health care provided by the team to the infant will be less if the procedure is refused), or inducements (no matter how apparently insignificant, e.g., the offer of a transport subsidy contingent on their agreement to the procedure) have the potential to influence the decision and are unacceptable.
  - Mental capacity of the parent or guardian: The parent or guardian is presumed to be competent and have the capacity to understand the medical information, to remember that

information, and to make logical inferences and conclusions from the information. If there is a definite indication that the parent or guardian is not competent, then the health care provider should not accept consent. At that time, the hospital attorney and the local court may become intimately involved in the case.

- The level of understanding of the parent or guardian: The information must be provided in language that the parent or guardian can understand. A qualified medical interpreter should be available if English is not the parent or guardian's first language; use of untrained personnel may lead to miscommunication.
- The risk/benefit for a given therapeutic intervention: The parent or guardian must be provided with information regarding the frequency and severity of the adverse potential consequences as compared to the likelihood, duration, and degree of anticipated benefit from the treatment(s). Where relevant benefits are questionable, the option of no treatment should also be discussed.
- Information overload: There are circumstances in which too much information may prevent the parent or guardian from making a decision. The parent or guardian may become overwhelmed with the options or potential adverse consequences and be unable to make any decision. Thus, the health care provider is not obliged to detail every statistically possible complication, even though highly unlikely (e.g., the possibility of exsanguination from an umbilical line in an infant with normal coagulation status).
- The limits of medical confidentiality: Current legal, medical, policy, and social considerations suggest that an informed consent contract with a parent or guardian needs to be defined in terms of relative rather than absolute confidentiality. Local, state, or federal regulations and laws may permit or require the reporting of medical and other information to third parties (e.g., state and federal law enforcement agencies, state and federal health agencies, insurance companies).
- The duty to warn and protect: A health care professional may have an ethical or legal duty to warn identifiable individual(s) that they have been or may have been exposed to disease or violence (contact tracing). There are some states that forbid physicians from notifying the sexual partners of patients infected with the human immunodeficiency virus (HIV). However, although the health care provider cannot force the infant's mother to inform the infant's biological father that she is infected with HIV, the health care provider can inform the infant's father that the infant is infected, regardless of whether the parents are married, especially if the father will be involved in raising the child and therefore needs to know about universal precautions.
- Duty to impute consent: There is a long-standing general medical principle that informed consent may be imputed to an unconscious accident victim who has a life-threatening condition that requires surgery. In an emergency, such rational behavior can also be imputed to the â€œabsent parentâ€□ of an infant. When time allows, prior consultation with the hospital administration and/or hospital attorney is recommended in matters involving infants whose parents or guardians are not available or who are unable to make the necessary acute or long-term medical decisions concerning the infant. In such instances, the hospital may be forced to petition the court to appoint a legal guardian. The court may accept its historic role of parens patriae (substitute parent) and make such an appointment (22).
- Court petitions for guardianship: The court can be petitioned for the appointment of a temporary legal guardian, if the parents are unavailable or unwilling to consent to a routine medical treatment such as a life-saving blood transfusion (even if the refusal is based on sincere religious convictions such as those held by Jehovah's Witnesses [22]). If the parents are unavailable and a reasonable attempt has been made to contact them, then continuing to withhold the emergency treatment because of the failure to obtain their consent may be a basis for malpractice liability. Involvement of hospital administrative personnel and legal consultation may be advisable in such circumstances.

- All parties must understand the basic elements of informed consent as it pertains to neonates (13,14,16,17 and 18,20,21,22 and 23
    - A clear and easily understandable description of the diagnosis, the procedure, and an explanation of why the procedure is necessary for the treatment of the neonate and what may occur if the procedure is not performed.
    - A clear and easily understandable description of the reasonably foreseeable risks or discomforts.
    - A clear and easily understandable description of the benefits to the neonate. In the case of participation in a research protocol, the informed consent must contain a statement that there may be no benefit to the infant or the family.
    - A disclosure of appropriate alternative procedures or course(s) of treatment, if any, that might be advantageous to the neonate. This should include a description of what will happen to the neonate if the procedure is not performed.
    - A statement describing the extent, if any, to which the records will be protected and whether the research subjects or their parent or guardian can be identified from the medical records during or after the conclusion of the research. The statement should also indicate that research records may be inspected by the FDA and other federal agencies.
    - A statement defining who can be contacted for additional information about the treatment procedure(s).
    - The signature of the health care provider who has discussed the contents of the informed consent with the parent or guardian and the signature of the parent or guardian, dated and usually witnessed by at least one person.
    - In addition to a signed informed consent form, the author recommends that the health care provider write a note in the patient's chart indicating that the critical elements contained in the informed consent were explained to the parent or guardian. This note should also include the name(s) of those who signed and witnessed the consent. The most important aspect of an informed consent is the process of communication; the hospital chart note is simply a record that such communication has occurred. It documents the major issues that have been discussed. The more significant the illness, the greater the risks of the procedure or not performing the procedure; the more information that needs to be conveyed to the treatment decision maker, the greater is the amount of detail that should appear in the medical chart.
    - In instances in which written consent cannot be directly obtained, consent may be obtained by telephone. In such an instance, a copy of the consent form, co-signed by any witness(es) (at least one) who heard the explanation and the consent being given, should be legally sufficient. A separate note in the patient's chart should also document the parties involved in the informed consent process and the general content of the material provided to the parent or guardian during the telephone conversation.
- The individual who provides the necessary details of the planned procedure must be competent to communicate the necessary information adequately to all concerned.
    - The health care provider who is going to perform or direct the therapeutic intervention is in the best position to obtain informed consent.
    - Consent can be obtained by anyone with the necessary training to understand and explain the details of the procedure and the relevant risks.
    - Allocation of scarce and costly medical resources has become a function of availability of the resources as well as financial accessibility to those resources. Third party payers such as insurance companies and health maintenance organizations (HMOs) have altered the manner in which medical treatment decisions are perceived to be made and actually are made (24,25). Under the â€œmanaged careâ€□ system, an individual or family may wish a particular procedure to be performed (e.g., the placement of a gastrostomy tube to facilitate home or institutional care), but the procedure will not be performed unless it is either approved by the third-party payer or, if disapproved, the family members or others agree to pay for it. Thus, the treating physician may also be required to obtain â€œinformed consentâ€□ from the

third-party payer as health care advocate for the patient. Thus, the individual responsible for obtaining consent for a procedure must be capable of gaining the trust of those to whom he presents information.

D. Policy and Regulatory Issues

- Medical records

The U.S. federal government has enacted the Health Insurance Portability and Accountability Act (HIPPA), which is administered, in large part, by the Department of Health and Human Services (DHHS), and specifically recognizes that the manner in which medical records are kept has evolved from handwritten notes maintained in filing cabinets in individual practitioners' offices to electronic databases that can be instantaneously shared with health care providers, vendors of health services, insurance companies, and employers. Patient privacy issues have become a national concern and appear to require national legislation and enforcement to ensure adequate protection. Disclosure of identifiable information, it is recommended, should be limited to the â€œminimum necessary to accomplish the purpose of the disclosure and should be used within an organization only for the purposes for which the information was collected (26).â€ However, there is a need for a pragmatic balance; health information has to be accessible to public health and emergency medical services.

Medical records pertaining to the care and treatment of infants present several unique problems. The patient is not competent to provide informed consent or restrict access to the records. Guardians or parents may not be in agreement as to the nature and extent of the treatment or who should have access to medical records. Regardless of who has the legal responsibility for providing that authorization for access, treating health care providers, in general, are presumed to have access to their patient's records. A requirement for a signed consent for a routine referral can impair care by delaying consultation and referral. Thus, a physician may refer a patient to another physician (at another medical facility, including a hospital or HMO) without a specific requirement for a release of medical information form.

The Uniform Health Care Information Act permits disclosure â€œto a person who is providing health care to the patient (27).â€ Of note, diagnostic interpretation of radiographic and other studies, through the use of telemedicine consultations, would appear to be covered under any statutes designed to protect medical confidentiality without compromising medical care.

Telemedicine and in-hospital consultations are conceptually similar.

The Health Insurance Portability and Accountability Act (HIPAA) of 1996 (28), required the Department of Health and Human Services (HHS) to put forth national standards for electronic health care transactions in such a manner as to prevent the erosion of the privacy of health information. However, the Law and the associated Regulations are not designed to impede the transfer of critical medical information via any media (verbal, written, or electronic) in the case of a serious or life-threatening condition. In other words, the law does not contemplate or require a delay in life-saving or other significant treatment because all the paperwork has not been properly completed. Some States have enacted â€œpatient bill of rightsâ€ legislation to protect the rights and needs of those who may not be able to protect themselves. If the state law is more restrictive than HIPAA, it will have precedence. When it comes to interpreting state and federal laws and regulations and guidelines, it is advisable to contact the hospital legal department.

- Medical confidentiality

  Patient-identifiable information should not be disclosed except as authorized by the patient or his or her guardian or as explicitly required by law. Security measures should be implemented to protect patient information against reasonably anticipated threats. Locking doors and cabinets at the end of a business day, limiting access to those who actually need to know about a given patient, and not discussing a patient by name or other identifiable characteristic in a public place continue to be part of the common-sense approach to medical confidentiality.

  While disclosures of identifiable information should be limited to the minimum necessary to accomplish the purpose of the disclosure, restricting information excessively may interfere with the diagnosis, treatment, and management of the patient. Parents and guardians should understand that, in a hospital or medical center setting, ready access to patient information is, of necessity, less restricted than it is in an individual clinician's office. For example, professional staff, unknown to the family, may have access to medical records for purposes of consultation or quality assurance. In addition, the tracking of medical pharmaceuticals and medical devices, legislated and required by the Federal Food, Drug and Cosmetic Act and enforced by the FDA (29), requires that physicians report informationâ€”sometimes including patient identitiesâ€”to device manufacturers (30). Does the failure to provide adequate information risk compromising patient care? This is the primary question to consider in making a decision to withhold or communicate critical and sensitive medical information.

E. Unresolved Problems

- When emotional stability, maturity, or sobriety (intoxication, regardless of the nature of the psychoactive substance) is an issue in obtaining informed consent for treatment, the physician has a duty to inform a third party (the hospital legal department and the hospital department of social services) and to document his or her actions in the medical record.
- Generally, if the parents are not legally married, the informed consent of the mother is considered more substantive than that of the father. Grandparents may advise the neonate's mother, but they cannot overrule her decision unless they have legal custody of the infant. When the parents are married and they are in conflict as to the course of action to be taken, both parents' consent should be obtained before proceeding. If there is no agreement, and the issue is substantive, the hospital attorney should be consulted.
- A nonpregnant teenager, living at home and attending school, is not considered emancipated. She may not have the right, under law, to make the ultimate decisions about some aspects of her own medical care. A teenager becomes emancipated when she reaches the age of majority (in most states, age 18 years), is a member of the armed forces, is living away from home and supporting herself economically, or can otherwise demonstrate financial independence from her family to the court. However, regardless of age and financial independence, once her child is born, she has the legal right, in almost all states, to make medical decisions for her child. Thus, a 13- or 14-year-old unwed mother usually has the ultimate legal and moral responsibility for the care of her child unless the court is successfully petitioned for the transfer of custody (including medical decision-making authority) to a third party such as a relative or other court-appointed guardian.

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2-Maintenance of Thermal Homeostasis

Dora C. Rioja-Mazza

A. Definitions

- Homeostasis: Fundamental mechanism whereby living things regulate their internal environment within tolerable limits, thus keeping a dynamic equilibrium and maintaining a stable, constant condition. From the Greek homeo (same, like) and stasis (stable state) (1).
- Normal temperature: The core body temperature is maintained by the term infant within the range of 36.5Â°C to 37.5Â°C, and the skin temperature, from 0.5Â°C to 1.0Â°C lower (2).
- Thermoneutral zone: The range of ambient temperature required for the infant (for each gestational age and weight) to keep a normal body temperature (core body temperature from 36.5Â°C to 37.5Â°C) and a minimal basal metabolic rate (2,3 and 4).
- Thermoregulation: Mechanisms by which the infant tries to balance heat production and heat loss to accommodate the thermal environment (5,6 and 7).
- Cold stress: The infant senses heat loss as a stress and responds with increased heat production and peripheral vasoconstriction, with centralization of circulation, in an effort to maintain the core temperature (8).
- Hypothermia: Heat losses exceed heat production, dropping the infant's temperature below normal range (9).
    - Mild hypothermia (cold stress): 36.0Â°C to 36.4Â°C (96.8Â°F to 97.5Â°F)
    - Moderate hypothermia: 32.0Â°C to 35.9Â°C (89.6Â°F to 96.6Â°F)
    - Severe hypothermia: below 32Â°C (89.6Â°F)
- Hyperthermia: An increase in the infant's temperature to above 37.5Â°C (99.5Â°F), due to a warm environment. Hyperthermia is less common than hypothermia but is equally dangerous. Clinically, it may be difficult to distinguish hyperthermia from fever (infectious origin); therefore, always consider both causes in any increase in temperature (9).

B. Background

- Effects of hypothermia:
    - Hypothermia may have severe consequences in newborn infants and may even lead to death (10,11).
    - Peripheral vasoconstriction: acrocyanosis, paleness, and coldness to touch
    - Respiratory distress, apnea, and bradycardia (12,13)
    - Depletion of caloric reserves and hypoglycemia, causing shift to anaerobic metabolism and lactic acid production (14,15)
    - Increased oxygen consumption and metabolic demands result in metabolic acidosisâ€”a strong pulmonary vasoconstrictor inducing hypoxemia and central cyanosis (16,17).
    - Mobilization of norepinephrine and free fatty acids. Norepinephrine release promotes pulmonary hypertension and pulmonary ventilationâ€“perfusion mismatch (18).
    - Risk of kernicterus at low levels of serum bilirubin (19)
    - Poor weight gain with chronic hypothermia (20)
    - Controlled hypothermia may have a neuroprotective effect in term and near-term infants with moderate to severe hypoxic ischemic encephalopathy (21,22).
- Effects of hyperthermia or overheating (9)
    - Peripheral vasodilatation: The skin is hot, the extremities are red, and the face is flushed. Diaphoresis present in full-term infants. Skin temperature is higher than core temperature.
    - Apnea, tachypnea
    - Tachycardia and hypotension

  - The infant assumes a spread-eagle posture.
  - Hyperactivity and irritability: The infant becomes restless and cries, then feeds poorly, with lethargy and hypotonia.
  - If hyperthermia is severe, shock, seizures, and coma may occur.
  - If the increase in temperature is due to hypermetabolism (infection), paleness, vasoconstriction, cool extremities, and core temperature higher than skin temperature may be noted.
- Factors affecting heat loss
  - Infant
    - Large surface area relative to body mass
    - Relatively large head with highly vascular fontanelle
    - Skin maturation/thickness, epidermal barrier functionally mature at 32 to 34 weeks. Transepidermal water loss may be 10 to 15 times greater in preterm infants of 25 weeks' gestation (4).
    - Decreased stores of subcutaneous fat and brown adipose tissue in more premature infants (7)
    - Inability to signal discomfort or trigger heat production (shivering) (7)
  - Environment (3,4)
    - Physical contact with cold or warm objects (conduction)
    - Radiant heat loss or gain from proximity to hot or cold objects (radiation)
    - Wet or exposed body surfaces (evaporation)
    - Air currents in nursery or in incubator fan (convection)
    - Excessive or insufficient coverings or clothing
  - Other factors
    - Metabolic demands of disease: asphyxia, respiratory distress, sepsis (11)
    - Pharmacologic agents, e.g., vasodilating drugs, maternal analgesics, and unwarmed IV infusions, including blood products
    - Medical stability of infant prior to procedure
    - Thermogenic response matures with increase in postconception age (4)

C. Indications

- Maintenance of thermal homeostasis is necessary at all times, but particular attention should be paid when the neonate is undergoing diagnostic or therapeutic procedures.
- Avoids increase in insensible water loss (IWL) and improves caloric utilization.

D. Equipment, Techniques, and Complications

- Prevention of heat loss in the delivery room
  - Provide a warm environment, room temperature >28.0Â°C; place infant on a radiant warmer, dry the skin with prewarmed blankets (9,14).
  - Use occlusive plastic blankets/bags (10,23).
    - Polyethylene bags (20 cm x 50 cm) prevent evaporative heat loss in infants <28 weeks' gestation. Their diathermancy allows transmission of radiant heat to the infant. Immediately after delivery, open the bag under the radiant warmer; wrap the wet infant's body from the shoulders down, and dry only the head. After stabilization, remove the wrap after the infant is inside a humidified incubator (23).
    - Environment: Maintains temperature and reduces IWL by 25% (23,24)
    - Access: Allows neonatal resuscitation (secure airway, intubation, and chest compressions), but vascular access is limited
    - Asepsis: Limited by access
    - Precautions: Record core temperature every 5 to 10 minutes until infant is stable.

        - Complications: Hyperthermia, skin maceration, risk of infection
    - Stockinette caps are not effective in reducing heat loss in term infants in the delivery room; there is insufficient evidence in preterm infants (10,24). Wool head coverings may reduce or prevent heat loss in term infants in the delivery room (24,25).
- Prevention of heat loss in the neonatal intensive care unit (NICU)
    - Rigid plastic heat shields (heat shielding)
        - Environment: Reduces IWL by 25% (26)
        - Access: Very limited
        - Asepsis: Limited by access
        - Precautions: Avoid direct skin contact.
        - Complications: Hyperthermia, skin maceration, risk of infection
    - Semiocclusive artificial skin (epidermal barrier protection) (27)
        - Tegaderm (3M, St. Paul, MN, USA). Semipermeable polyurethane membrane; application to extremely low-birthweight (ELBW <1,000 g) infants shortly after birth decreases fluid imbalance, allows electronic monitoring through membranes, and avoids adhesive injuries
        - Environment: Reduces IWL and improves skin care
        - Access: Limited in the area covered
        - Asepsis: Needs to be removed completely before any asepsis
        - Precautions: Thermal control inefficient for <1-kg infants
        - Complications: Risk of infection
    - Petroleum-based preservative-free ointments (epidermal barrier protection)
        - Aquaphor Original Emollient Ointment (Beiersdorf, Norwalk, CT, USA)
        - Use of this type of ointment has been discouraged in extremely low-birthweight infants (<1,000 g) because of evidence showing increase in nosocomial bacterial sepsis, caused mainly by coagulase-negative Staphylococci (28,29).

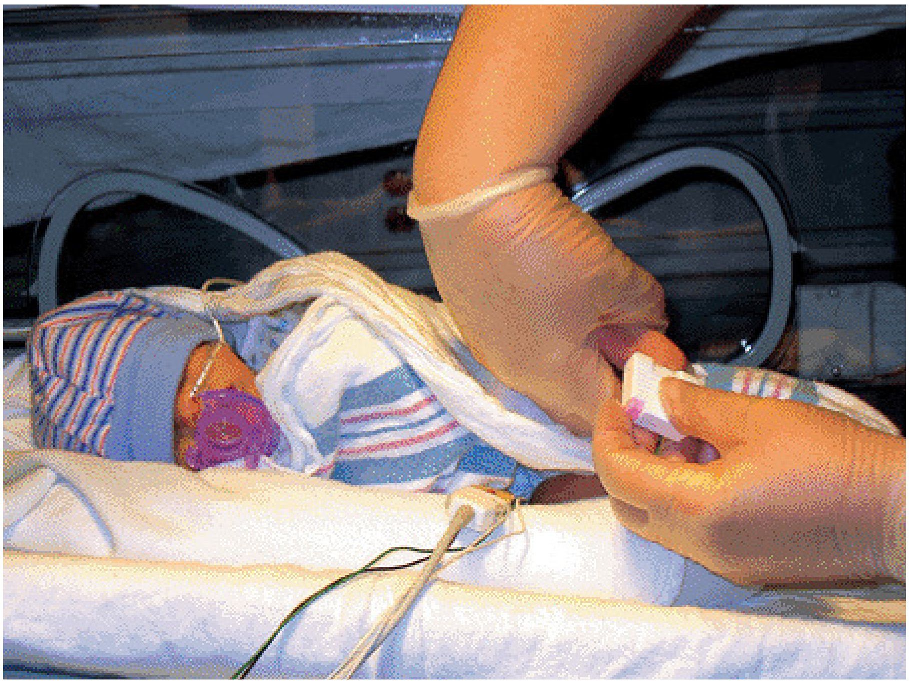

FIG. 2.1. All aspects of homeostasis are maintained during a procedure by use of an extra heat source, swaddling, stockinette cap, comfortable position, and sucrose/analgesia pacifier.

- Mechanical devices to maintain temperature
    - Thermal resistor (thermistor): A probe placed on the anterior abdominal wall or interscapular area. Used to servocontrol incubator/radiant warmer to keep infant temperature between 36.0Â°C and 36.5Â°C (4,30)
    - Convection-warmed incubator (Fig. 2.1)
        - Environment: Creates a microclimate for each infant. Infant servocontrol (ISC) triggered by skin or air temperature; temperature can also be set manually. Double plastic walls, insulated mattress, and forced-heated/humidified air minimize IWL and maintain temperature.
        - Access: Impeded by portholes, especially when working with assistants. Improved with new incubators/warmers to allow better access [e.g., Giraffe Omnibed neonatal care station (GE Medical Systems, Waukesha, WI, USA)]
        - Asepsis: Impossible to maintain wide sterile field and infant position
        - Precautions: Take infant's temperature before and after procedure. Use ISC and ensure that thermistor remains in place. Add extra heat source (heat lamp) for unstable infants or stressful procedures. Clinical deterioration may require lifting the protective shield.
        - Complications: Hyperthermia, hypothermia, unexpected break of aseptic field
    - Radiant warmed bed: For unstable infants (30)
        - Environment: Increases IWL by 50% in small preterm infants.
        - Access: Unimpeded access to infants receiving intensive care
        - Asepsis: Ability to maintain infant position and wide sterile field; also allows assistants to participate
        - Precautions: Keep infant 80 to 90 cm from radiant heat. For premature infants, heat shielding must be added. Increase fluid infusions. Record temperature every 5 to 10 minutes or use continuous monitor. To avoid burns, do not place oily substances on infant's skin.
        - Complications: Hyperthermia and dehydration
    - Heat lamp: As an extra heat source (30)
        - Environment: Increased IWL
        - Access: Limited by other equipment used (open incubator, bassinette walls)
        - Asepsis: May be affected by limited access
        - Precautions: Record temperature every 5 to 10 minutes or use continuous monitor. To avoid burns, do not place oily substances on infant's skin. Avoid heating incubator thermometer; apply manual temperature control (33Â°C to 35Â°C) when using open incubator. Keep infant approximately 60 to 90 cm from lamp bulb, and cover infant's eyes and genitals to protect from the light.
        - Complications: Cooling or overheating of isolette due to failure to detach the thermistor from infant; dehydration
    - Warming mattress: Extra heat source, for transport or radiology procedures (e.g., MRI). Effective in preventing and treating hypothermia in premature infants (<1,500 g) in the delivery room (10,24)
        - Environment: Heating through conduction, reduces heat requirements and IWL
            - Heated water-filled mattress (keep at 37.0Â°C)
            - Exothermic crystallization of sodium acetate mattress (Transwarmer Infant Transport Mattress, Prism Technologies, San Antonio, TX, USA) with a postactivation temperature of 39.0Â°C Â± 1.0Â°C
        - Access: Limited only by other equipment used
        - Asepsis: Limited only by other equipment used
        - Precautions: Record temperature every 10 to 20 minutes or use ISC continuous monitor
        - Complications: Hypothermia, hyperthermia, burns

E. Special Circumstances/Considerations

- Regulate room temperature to one optimal for infant (28Â°C to 30Â°C) (9).
- Prewarm all heating units, including radiant warmers and incubators
- Remember that very low-birthweight preterm infants, and infants during the immediate newborn adaptation period, are more vulnerable to hypothermia and IWL.
- For transport outside of the NICU, use heated, battery-operated transport double-walled incubator.
- Plug incubator into wall outlet during procedure to allow battery to charge.
- Be aware that anesthesia may inhibit the infant's thermoregulatory capabilities.
- Warm all anesthetic and respiratory gases to body temperature and humidify.
- Gastrochisis/omphalocele: These abdominal wall defects increase risk of heat loss, fluid imbalance, and visceral damage. The infant may be placed in a â€œbowel bagâ€□ from the torso down, or the entire abdomen may be wrapped in clean, clear plastic wrap. Avoid visceral ischemia by keeping intestines directly above the abdominal wall defect or keep the infant in right lateral decubitus position (31).
- Neural tube defects. Keep the infant in prone position, cover the lesion with sterile gauze (soaked in warmed sterile saline), then wrap the trunk circumferentially with a dry gauze, finally covering the dry gauze with plastic wrap to minimize insensible water losses and prevent hypothermia (32).

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3-Methods of Restraint

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Physical restraints are required for proper positioning for certain procedures. Infants may also need to be restrained to prevent accidental injury or interference with treatment (i.e., removal of feeding tubes, catheters, etc.). Select the least restrictive but most appropriate restraint for the individual patient.
A. Definitions

- Physical Restraint: â€œany device, garment, material, or object that restricts a person's freedom of movement or access to one's bodyâ€ (1)

B. Indications
Restraints should be utilized:

- When procedures require proper positioning to maintain asepsis and facilitate access to patient (IV placement, lumbar punctures, radiographs, etc.) (1)
- To reduce the risk of interference with treatment (removal of feeding tubes, IV access, mechanical ventilation, etc.) (2)
- To prevent accidental injury

C. Contraindications
Restraints should not be utilized:

- When close observation of the patient could protect against potential injury or potential interference with treatment (3)
- When a change in treatment or medication regimen could protect against potential injury or interference with treatment (3)
- When modification of the patient's environment (decreased stimuli, appropriate developmental positioning, reduced noise) could protect against potential injury or interference with treatment (3)
- When use of a restraint could compromise patient care, procedures, or emergency access (1)

D. Techniques
Restraints for Procedures/Positioning

- Mummy Restraint
    - Purpose: Safe temporary method for restraining young children for treatment or examination; allows for unimpeded access to head and scalp; individual extremities can be released for access for examination or treatment (1)
    - Equipment:
        - Commercially available restraint (â€œpapoose boardâ€□) for larger infants

      OR

        - Clean blanket or small sheet
        - Safety pins or other device for securing final blanket fold
    - Procedure (1):
        - Open blanket or sheet.
        - Fold one corner toward the center.
        - Place infant on blanket with shoulders at fold and feet toward opposite corner (Fig. 3.1 A).
        - With infant's right arm flexed and midline, tuck right side of blanket across trunk and under left side of body (Fig. 3.1 B).
        - Fold lower corner up toward head and tuck under left shoulder (Fig. 3.1 C).
        - With infant's left arm flexed and midline, tuck left side of blanket across trunk and under right side of body. Be sure to secure arms under blanket (Fig. 3.1 D).
- Extremity Restraint (wrist or ankle) (Fig. 3.2.)
    - Purpose: Immobilization of one or more extremities; protects infant from interfering with or removing treatment regimens (IV access, feeding tube, mechanical ventilation, etc.)
    - Equipment:
        - Commercially available restraint (sheepskin and/or foam padding) for larger infants

          OR

        - Roll of gauze or gauze pads
        - Adhesive tape
        - Safety pins or other securing device

- Procedure
    - Open gauze and fold in half lengthwise to reinforce material.
    - Wrap wrist or ankle with gauze at least three times to create secure restraint. Caution: Do not wrap gauze too tight; this might interfere with distal circulation.
    - Use adhesive tape to ensure that gauze does not unravel.
    - Secure restraint to mattress, blanket, or light sandbag with safety pin.

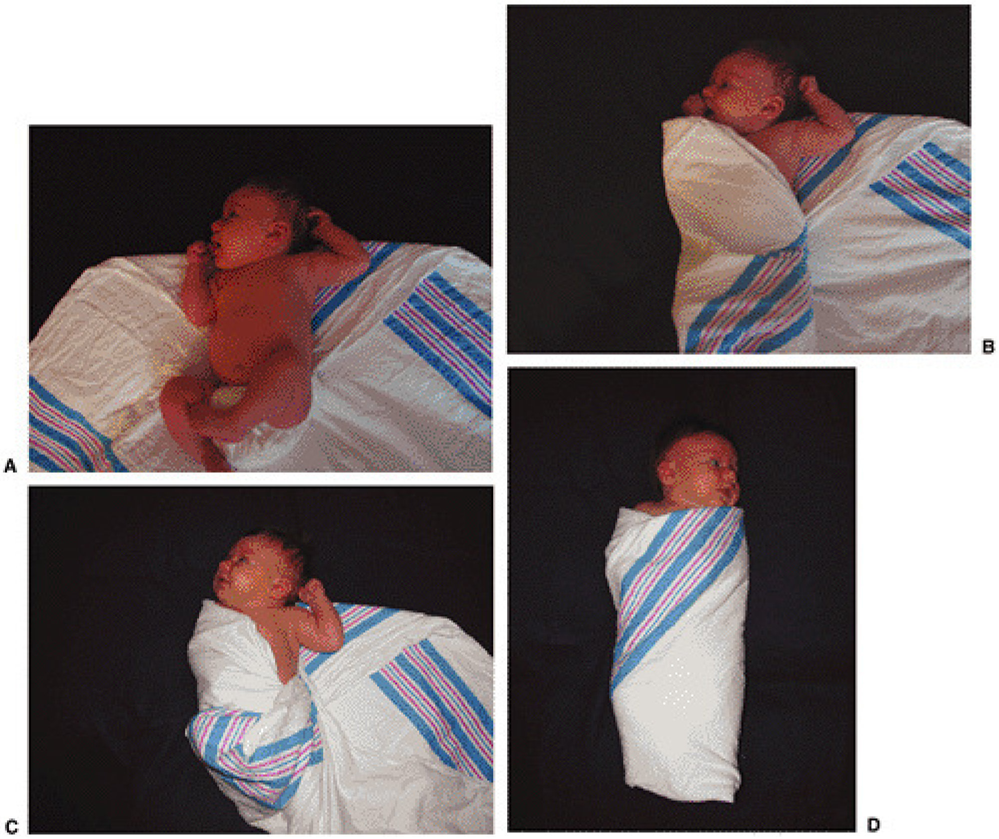

FIG. 3.1. A: Mummy restraint: steps (1)â€“(3). B: Mummy restraint: step (4). C: Mummy restraint: step (5). D: Mummy restraint: step (6).

- Mitten Restraint
    - Purpose: Thumbless device to restrain or cover hand; eliminate infant's ability to grasp and possibly dislodge necessary treatment regimens (IV access, feeding tube, mechanical ventilation, etc.); prevent infant from scratching self or removing dressings, interfering with maintenance of skin integrity
    - Equipment:
        - Commercial mittens

      OR

        - Stockinette material (cut to fit individual infant)
        - Adhesive tape
        - Safety pins or other securing device (optional)

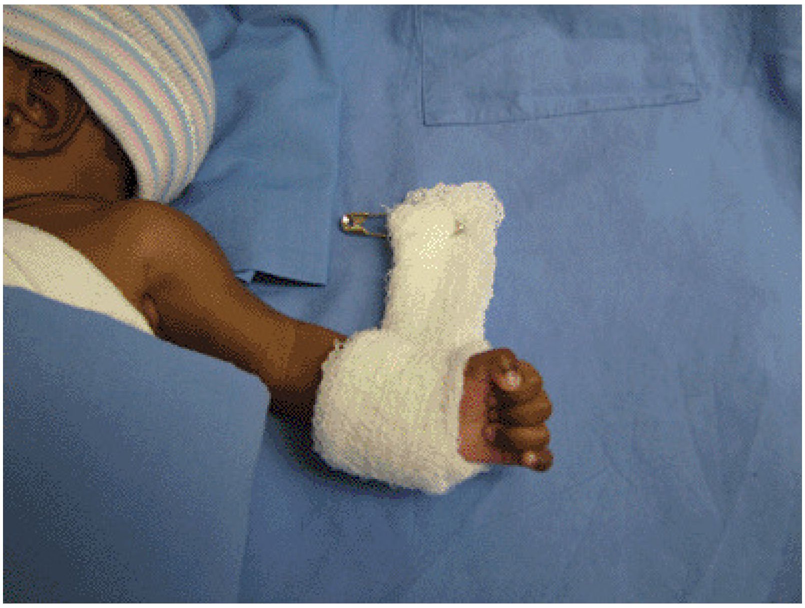

FIG. 3.2. Extremity restraint (wrist).

  - Procedure
    - Place infant's hand inside stockinette
    - Secure stockinette by applying tape to stockinette material and fastening around infant's wrist. Caution: Do not wrap tape too tight; this might interfere with distal circulation.
    - Tie end of stockinette in order to isolate fingers inside the stockinette material.
    - Secure restraint to mattress, blanket, or light sandbag with safety pin (optional).
- Elbow Restraint (Freedom Splint) (Fig. 3.3)
  - Purpose: Reduces ability of infant to flex elbow
  - Equipment:
    - Commercially available restraints (sheepskin and/or foam padding) for larger infants

    OR

    - Foam-padded armboard
    - Adhesive tape
    - Additional padding material, i.e., cotton balls, gauze pads
  - Procedure:
    - Cut four pieces of tape (appropriate size; tape should not completely encircle extremity).
    - Extend upper extremity.
    - Place armboard under elbow in order to eliminate ability to flex joint.
    - Tape extremity securely to armboard. Tape should be applied above and below elbow joint.
    - Pad bony prominences with cotton as needed.

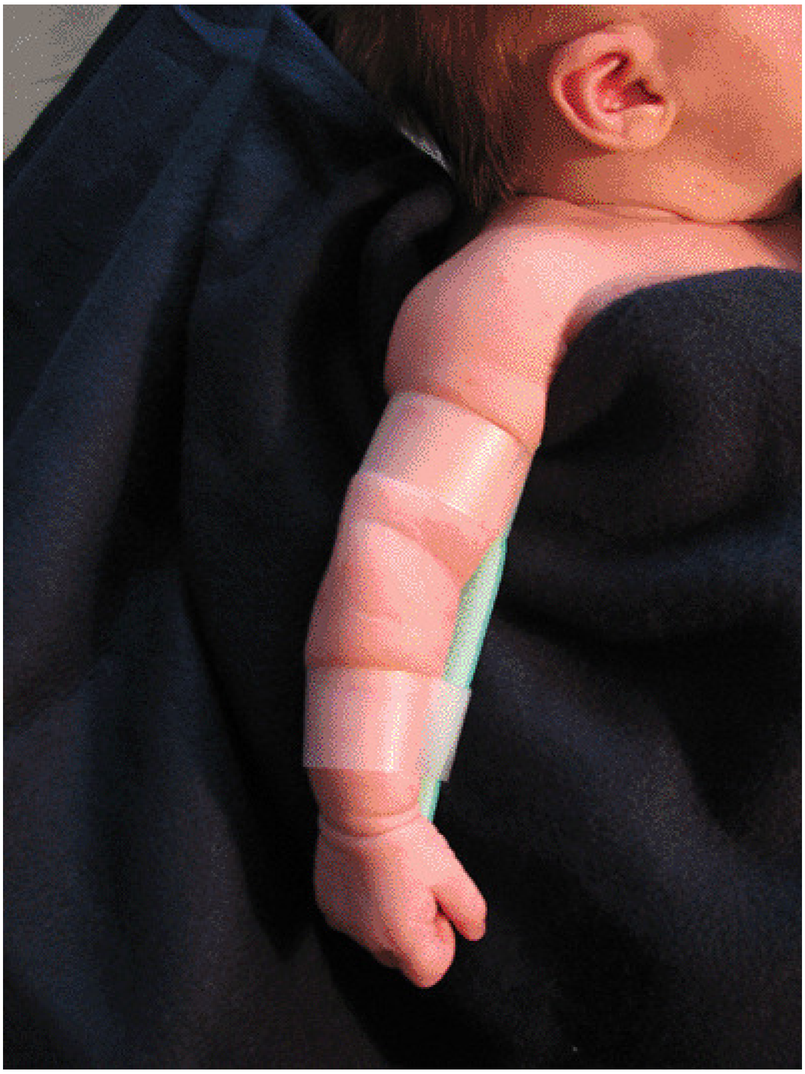

FIG. 3.3. Elbow restraint.

Restraints for Vascular Access

Restraints can be used to secure IV access and prevent accidental dislodgement.

- Equipment
    - Restraint device, i.e., armboard. Armboards vary in size; a larger infant may require an armboard that is 1 to 2 cm wider than the hand/foot and extend from the proximal joint to the distal joint. However, to maintain functional position and natural curvature of the hand at rest for long-term restraint, the armboard can be shorter in length to allow for curvature of fingers around the end of the board.
    - Adhesive tape. Transparent tape is recommended for visualization of IV site especially during continuous infusion.
    - Additional padding material, i.e., cotton balls, gauze pads

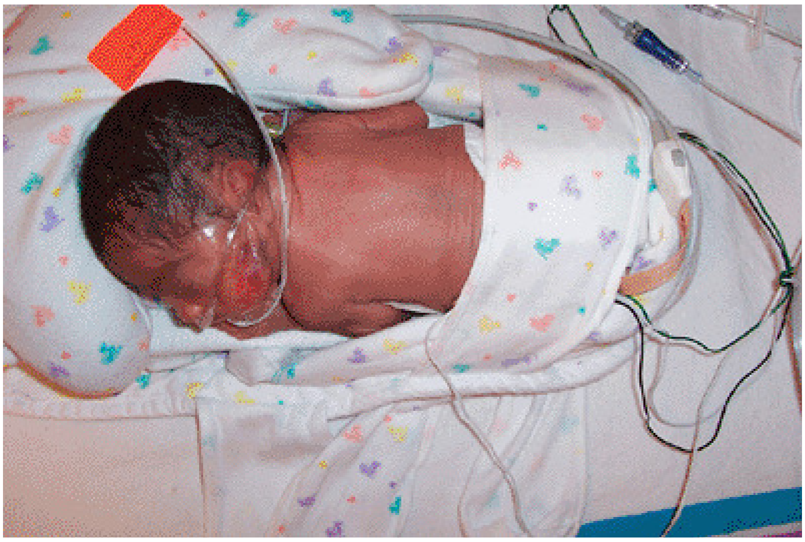

FIG. 3.4. Prone positioning during procedures and at rest provides for improved breathing and sleep, lower expenditure of energy, and more stable physiologic functioning (4). Care must be taken to create positioning support of the trunk and hips.

- Procedure
    - Ensure that the infant is in a correct and functional position.
        - Rationale: Prevention of contractures and supports self-calming techniques of neonates (prone, side-lying) (Figs. 3.4 and 3.5) (4)
    - Assess skin integrity where restraint is to be applied.
    - Apply restraint board using transparent tape. Do not allow tape to encircle extremity. Three pieces of tape should sufficiently restrain extremity and allow for visualization of the tips of fingers (Fig. 3.6) or toes (Fig. 3.7). The sequence of tape allows for functional positioning of thumb and ankle.
    - Pad bony prominences and maintain natural curvature of extremities (especially the hand and fingers).

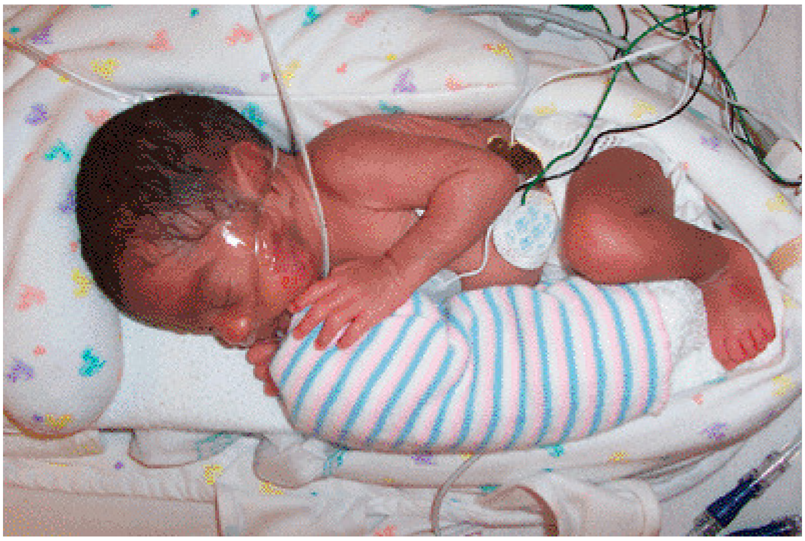

FIG. 3.5. Side-lying positioning is the best alternative to prone for procedures and sleeping. This position allows for more midline positioning of the upper and lower extremities. Nesting support increases postural stability and decreases arching of the back (4).

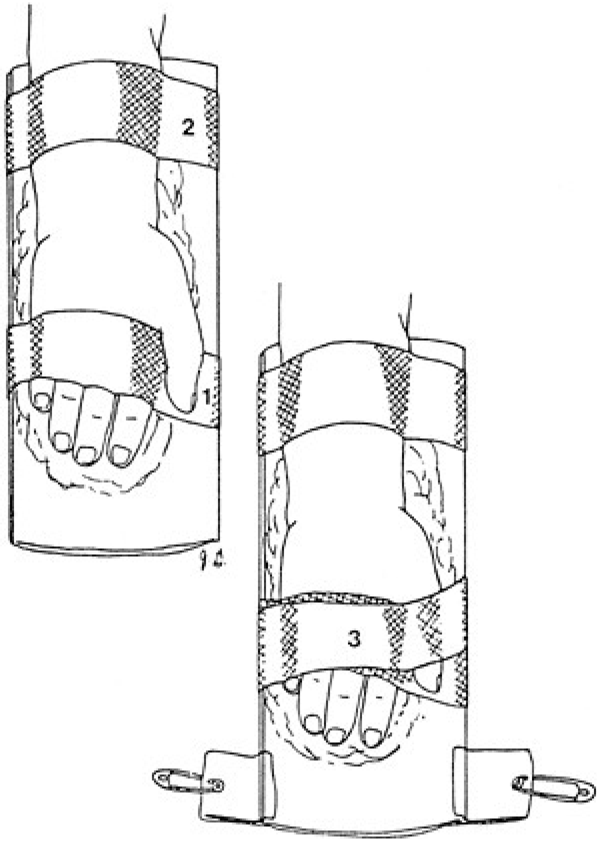

FIG. 3.6. Restraint for vascular accessâ€”wrist and forearm. Tape is applied in order, 1 through 3, as shown.

E. Precautions

- Restraints should be a last resort after other reasonable alternatives have failed including close observation, treatment and/or medication change, modification of environment, etc. (3).
- Family education regarding the need, procedure, and time frame for the use of the restraint is required. Provide opportunity for collaboration with the family. If possible, remove the restraints when the family is visiting (1).
- For restraints during procedures, proper techniques for analgesia, sedation, and distraction (pacifier, touch, sound, etc.) are necessary in addition to the restraint.
- Weigh equipment required for restraints (i.e., armboards) prior to use. If possible, maintain a list of the weights of common restraint materials in use when weighing infants for monitoring daily growth.
- Evaluate proper use, placement, and position of restraint at least every 2 hours or sooner according to patient need, hospital policy, and regulatory agency requirement. Regulatory agencies such as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), the U.S. Food and Drug Administration (FDA), and the Centers for Medicaid and Medicare Services publish standards of medical care regarding the safe use and legal requirements for restraint implementation and maintenance (1).
- Ensure that the infant is in a proper and functional position that promotes flexion and midline positioning of upper and lower extremities.
    - Rationale: Prevention of contractures and supports self-calming techniques of neonates (prone, side-lying) (Figs. 3.4 and 3.5) (4)
- Pad bony prominences and maintain natural curvature of extremities (especially the hand and fingers)
    - Rationale: Prevents contractures and neurovascular injury; preserves skin integrity; reduces friction and pressure to skin from restraint material (1)
- When utilizing tape for securing an extremity to a board, use transparent tape when possible to allow for careful and complete assessment of the underlying skin. Do not apply tape too securely or impede circulation. Tips of the digits should remain visible for assessment.

- Restraints on the upper or lower extremities need to be assessed at least hourly for:
    - Skin Integrity, including excoriation, erythema, and edema
    - Pulses
    - Temperature
    - Color
    - Capillary Refill
    - Range of Motion (ROM) (1)
- Check for vascular circulation by inserting two fingers between infant's skin and the secured restraint (1).
    - Rationale: Constriction from a tight restraint can cause neurovascular injury and impede circulation.
- Reassess and remove restraint at least every 2 hours and with patient care (or according to individual hospital policy).
    - Rationale: Regular assessments of circulation and skin integrity and passive ROM of the joint reduce the risk of neurovascular injury and skin impairment.
- Specific assessments related to oxygenation, musculoskeletal system, and cardiorespiratory conditions need to be performed in relation to the restraint device and its usage (1).
- Observe any treatment equipment for proper positioning and patency, especially in close proximity to the restraint device (kinked IV access, dislodgement of catheters, etc.) (1).

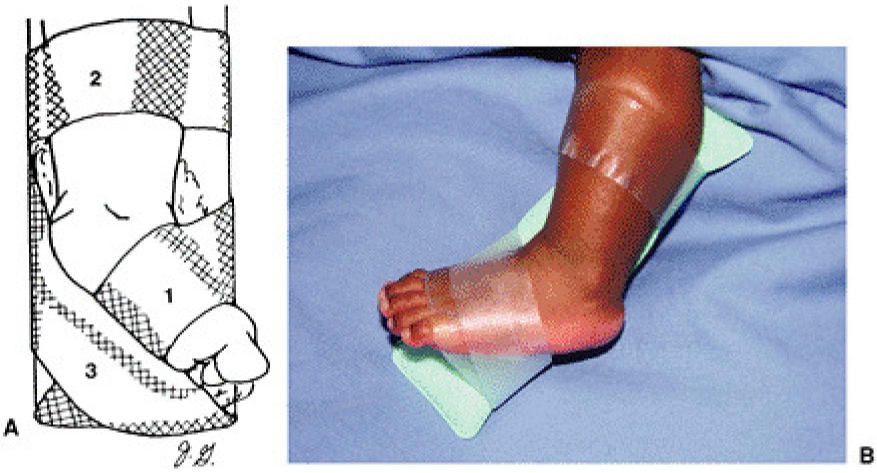

FIG. 3.7. A: Restraint for vascular accessâ€”foot and ankle. Tape is applied in order 1 through 3, as shown. B: Foot and ankle restraint for vascular access on premature infant.

- Attach restraint to fixed location on bed (if necessary), maintaining opportunity for quick release and regular vascular checks (safety pin, secure tucking, etc.). Do not attach restraint to equipment that can be moved in such a way as to create injury or pressure to restrained joint or skin surface (crib side rails, isolette doors). Quick release allows for mobility and access in an emergency.
- Document restraint use and, if required, obtain physician order (see hospital policy).
    - Rationale: Documentation of location, time, and specific assessments maintains a record of the intervention and specific assessments that were performed. Regulatory agencies, e.g., JCAHO, FDA, and Centers for Medicaid and Medicare Services, have published standards of care addressing the documentation of patient restraints (1).
- Remove restraint at the earliest time possible.

F. Complications

- Failure of restraint resulting in self-injury and/or interference with treatment
- Neurovascular impairment (1)
- Impairment of skin integrity (i.e., pressure ulcer formation, necrosis) (1)

- Contractures or positional deformity/paralysis from prolonged immobility (1)
- Limb injury (fracture or dislocation) from movement of infant without release of secured restraint or from securing restraint to movable object (e.g., crib side rails, isolette doors) (1)
- Impairment or compromise of medical state, including oxygenation, musculoskeletal system, and cardiorespiratory conditions (1)
- Increased agitation or irritability (3)
- Extravasation injury leading to impairment of skin integrity, tissue necrosis, infection, and/or nerve and tendon damage (5)

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4-Aseptic Preparation

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Khodayar Rais-Bahrami

A. Definitions

- Antiseptic
    - Bactericidal or bacteriostatic substance that can be safely applied to skin
    - Not reliable as a sporicidal
    - Reduces but does not eliminate bacterial counts on the skin
        - Has an immediate effect
        - May have variable residual activity by binding to the stratum corneum of the skin
- Disinfectant
    - Chemical germicidal
    - Not sporicidal
    - Too harsh to be used on skin
- Resident flora
    - Organisms, usually of low virulence, which survive and multiply on skin and can be cultured repeatedly, e.g., Staphylococcus epidermidis
    - Cannot be completely eradicated without destroying the skin
    - Regenerate rapidly on skin when surgical gloves are worn
- Transient flora
    - Organisms that are sometimes pathogenic but do not survive and multiply on skin, e.g., gram-negative organisms such as Escherichia coli
    - Can be transmitted to patients on the hands of health care workers
    - Do not usually remain on the skin for more than 24 hours
    - Can be eradicated completely by hand washing with antiseptic solutions

B. Background

Bloodstream bacterial infection is an extremely common complication of prematurity. The majority of etiologic pathogens are nosocomial, most often transmitted by health care personnel. Use of aseptic technique is critical in reducing the number of bloodstream infections as well as in decreasing the number of contaminated blood cultures, which in turn leads to a decrease in the unnecessary use of antibiotics and the potential for antibiotic resistance. Protocols and procedures for aseptic technique in neonatal intensive care units (NICUs) are constantly being re-evaluated and updated, and hand hygiene guidelines are routinely published by the U.S. Centers for Disease Control (CDC) (1,2). Hospital managers continuously develop and update strict policies and regulations (3) as well as quality improvement projects aimed to promote adherence to aseptic technique and hand hygiene (4).

C. Indications

- Preparation of patient's skin and the hands of personnel prior to performing a procedure
  - To remove transient flora
  - To remove and temporarily suppress most resident skin flora
- Decontamination of hands after a procedure

D. Contraindications

- Iodine solutions for preparation of skin in newborns [may cause skin and thyroid problems in high concentrations (5, 6 and 7)]
- Halogenated bisphenols (e.g., hexachlorophene) for preparation of skin in premature infants (see E7)
- Chlorhexidine for preparation of external auditory meatus

E. Precautions

- Universal (8,9)
  - Definition: A method of infection control in which all human blood and certain human body fluids are treated as if known to be contaminated with human immunodeficiency virus, hepatitis B virus, and other blood-borne pathogens
  - Indications: Reasonably anticipated risk of skin, eye, mucous membrane, or parenteral contact with blood or other potentially infectious materials, including semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, saliva in oral procedures, and any body fluid that is visibly contaminated with blood.
  - Major components
    - Use gloves when touching blood, body fluids, mucous membranes, or nonintact skin and when handling items or surfaces soiled with blood or body fluids.
    - Use a mask and eye protection during procedures that might generate splashing or droplets in the air.
    - Use a gown or a plastic apron when splashing of blood or body fluid is likely.
    - Wash hands carefully if they become contaminated with blood or body fluids.
    - Take extraordinary care in handling needles and other sharp objects, and dispose of them in puncture-resistant containers.
    - Exclude from patient care all personnel with exudative lesions or weeping dermatitis until these conditions have resolved.
- Recognize that no antiseptic is totally effective or without risk (Table 4.1).
- Always allow antiseptics to dry before starting procedure.
  - Drying time of at least 30 seconds is required for optimal effect (10).
  - Contamination of instruments with antiseptic is undesirable and may invalidate specimens taken for culture.

- Avoid removal of iodophore preparations prior to procedure. Removal negates the residual slow-release effect.
- After the procedure, remove iodophore from all but immediate area of procedure to prevent absorption through skin (5,6 and 7).
- Never allow antiseptic to pool under infant. Skin damage may result (16).
- Use hexachlorophene for skin preparation in newborns only as recommended by the American Academy of Pediatrics (17).
    - Use only in term infants during outbreak of Staphylococcus aureus infection.
    - Do not apply more than twice to each infant, unless application is restricted to diaper area (18).
    - Wash off solution completely.
- Reapply alcohol prior to each attempt at procedure or with any delay, as efficacy is short-lived and flora will regenerate quickly.
- Keep all antiseptics away from eyes.
- Store antiseptics in closed containers. Reusable dispensers should be thoroughly cleaned, dried, and refilled frequently. Disposable containers are available.
- Remember that gloving cannot be used as an alternative to hand washing.
    - The warm, wet skin surface under gloves offers an ideal environment for bacterial multiplication.
    - Gloves are not completely impermeable to microorganisms.
    - Latex and vinyl gloves offer comparable permeability, but vinyl gloves leak more readily.

F. Special Circumstances

- In clinical situations where traditional hand-washing facilities are unavailable, such as during patient transport, alcohol-based hand rinses, foams, or wipes may be used for hand cleaning. When alcohol solution is used, make three to five applications of 3 to 5 mL each; rub hands well until completely dry. Gloves should be used as otherwise indicated. This technique is not adequate when hands are soiled with organic matter.
- In cases of medical emergency, aseptic technique should be used as allowed by the situation, with at least use of skin preparation of the patient with an antiseptic, use of gloves, and sterile field as large as possible under the circumstances.
- Personnel suffering from allergies to antimicrobial soaps may wash thoroughly for 3 to 5 minutes with plain soap or 70% isopropanol with glycerin prior to gloving (19).
- Personnel suffering from skin cracking due to frequent use of antiseptic soaps may use skin lotions after hand washing. Products with a bacteriostatic ingredient, such as gels containing 60% ethanol, and emollients, are safe and effective in reducing skin problems (20). Containers with a flip top, rather than a screw cap, are recommended. Doebbeling et al. (21) have shown that a hand disinfection system using an antimicrobial agent (chlorhexidine) reduces the rate of nosocomial infection more effectively than one using alcohol and soap.
- Nonâ€"latex-containing gloves should be available for staff with latex allergy and to avoid allergic reactions in the patient, particularly in susceptible patients such as those with myelomeningocele (22,23).

TABLE 4.1 A Comparison of Commonly Used Antiseptics (11,14,15)

Considerations	Iodophor	Chlorhexidine (0.5%â€“4%)	Alcohol (70%â€“90%)	Iodine (1%)	Hexa-chlorophene 3%)	Chloroxylenol (PCMX) (0.5%â€“3.5%)
1. Indications	Hand washing Skin preparation	Hand washing: 4% Skin preparation: 0.5% in 70% alcohol optimal. May be superior to alcohol alone or iodophor in preventing central line infection (adult data).[a]	Skin preparation for minor procedures Preparation of external auditory canal	Surgical hand washing as tincture with alcohol	Hand washing Use limited to term infants during epidemics of MRSA	Hand washing Skin and wound disinfection
2. Effective concentration						
a. Nontoxic	Hypothyroidism	Yes,[b] but local ototoxicity	Yes[c]	Hypothyroidism	CNS vacuolation	Yes[b]
b. Nonsensitizing	Yes	Yes	Yes	No	Yes	Low
c. Nonirritating	Yes	Yes	Burns in premature infants	No	Yes	Yes
3. Mode of action	Oxidation	Cell wall disruption	Protein denaturation	Oxidation	Cell wall disruption	Cell wall disruption and enzyme inactivation
4. Bactericidal	Yes	Yes	Yes	Yes	No	Yes
5. May be used with detergent	Yes	Yes	No	No	Yes	Neutralized by nonionic surfactants
6. Persistent local action	Yes	Yes	No	Yes	Yes, but only with repeated use; reduced by concomitant use of alcohol	Good
7. Effective against						
a. Gram-positive bacteria	Yes	Yes	Yes	Yes	Yes (bacteriostatic)	Good (better against Streptococcus than Staphylococcus)

b. Gram-negative bacteria	Yes	Yes	Yes	Yes	No	Fair, improved by EDTA
c. Spores	No	No	No	No	No	No
d. Tubercle bacillus	No	No	Yes	Yes	No	Fair
e. Viruses	Yes	Yes	Lipophilic viruses only	Yes	Yes	Fair
f. Fungi	Yes	Yes	Yes	Yes	Yes	Fair
8. Use associated with resistance	No	Contamination with *Pseudomonas* and *Proteus* species	No	No	Yes	Not effective against Pseudomonas species
9. Rapid action	No Requires 4â€“5 min of scrubbing	Yes (better when combined with alcohol)	Yes (drying time)	Yes	No	Intermediate
10. Easily inactivated by extraneous organic matter	No Low surface tension for good crevice and fat penetration	No	May be inactivated by nonbacterial protein	Yes	Yes	Minimal

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MRSA, methicillin resistant staphylococcus aureus; CNS, central nervous system; EDTA, ethylenediaminetetra-acetic acid.

[a] Data from Maki et al. (11).

[b] Skin absorption not studied in very low-birthweight infants.

[c] Data from Harpin and Rulter (39).

G. Technique (See Procedures DVD for Video)

A 3- to 5-minute â€œscrubâ€□ (vigorous washing up to the elbows) is necessary upon entering the nursery. Subsequently, a 15- to 30-second handwashing is indicated prior to and after each patient contact.

- Preparation for a minor procedure
    - Definition of a minor procedure
        - Short duration (5 to 10 minutes); noncomplex
        - Does not involve an area, such as the central nervous system (CNS), which is especially vulnerable to infection
        - Does not require skin incision
        - For example, blood drawing, placement of percutaneous peripheral venous line, bladder tap, punch-skin biopsy
    - Preparation of personnel
        - Wear cap/beard cover if hair is likely to contaminate the field.
        - Remove all jewelry from hands and arms.
        - Wash hands, wrist, forearms, and elbows using a small amount of antiseptic preparation (e.g., iodophore or chlorhexidine). Iodophore preparations appear to be equally effective when applied with disposable sponges or brushes. Vigorous scrubbing with a brush leads to skin breakdown and possible contamination and is contraindicated. Be sure to include between the fingers and the lateral surface of the fifth finger.
        - Clean nails with stick.
        - Wash/scrub hands and forearms to elbow with antiseptic for a further 2 to 3 minutes.
        - Rinse hands and forearms with running water, keeping them elevated above elbows.
        - Use towel to shut off water if knee- or foot-operated faucets are not available.
        - Dry hands with clean towel prior to drying forearms.
        - Wear gloves.
    - Preparation of patient skin
        - If necessary, cut hair in area of procedure with small scissors, taking care not to nick skin. Avoid shaving, as that may cause skin compromise and increases the risk of infection.
        - Apply antiseptic.
            - Alcohol may be used. Preparation with iodophore may be optimal, but color tends to obscure underlying vessels.
            - Apply three times in circles progressing away from procedure site.
            - Apply with some friction.
            - Allow to dry. Do not wipe off antiseptic.
            - Never touch skin after application of antiseptic and before initiation of the procedure.
            - If using alcohol, reapply it prior to every attempt at procedure.
- Preparation for a major procedure
    - Definition of major procedure
        - Invasive or involving skin incision
        - For example, central line placement, cutdown, chest tube, lumbar puncture
        - Duration longer than 5 to 10 minutes
    - Masks, drapes, and gowns. Clothing is an important barrier to microorganisms shed into the air from the skin and mucous membranes. The pore size of gowns and masks should prevent bacterial passage even when wet [use 140 thread count or higher unless plasticized (24)]. Disposable gowns and drapes manufactured from nonwoven materials are effective in reducing infection (25). When woven reusable materials are used, they should be tightly woven and treated with a water repellent.

    - Put on cap and mask.
    - Clean nails and â€œscrubâ€ as for minor procedure, but continue for 4 to 5 minutes.
    - Rinse forearms and hands, keeping them elevated above elbows.
    - Dry hands and then forearms with two sterile towels. Keep wrists and hands elevated until drying is complete.
    - Put on sterile gown with the aid of an assistant (Fig. 4.1).
    - Put on sterile gloves, without contaminating external surface with ungloved hand (Fig. 4.2).
        - Have assistant open packet without contaminating contents.
        - Pull gloves well over sleeve ends.
- Preparation of patient skin
    - Prior to procedure, have assistant:
        - Wash area, if soiled, with soap and water.
        - If necessary, remove hair using small scissors, taking care not to nick skin. Do not shave the area.
    - Apply antiseptic with three separate sponges. Start at center of circle, and work centrifugally to at least 5 cm outside immediate area of procedure. Alcohol (70%) should not be used. An iodophore preparation is commonly used in nurseries in the United States.
    - Allow antiseptic to dry. Do not wipe off antiseptic prior to procedure.

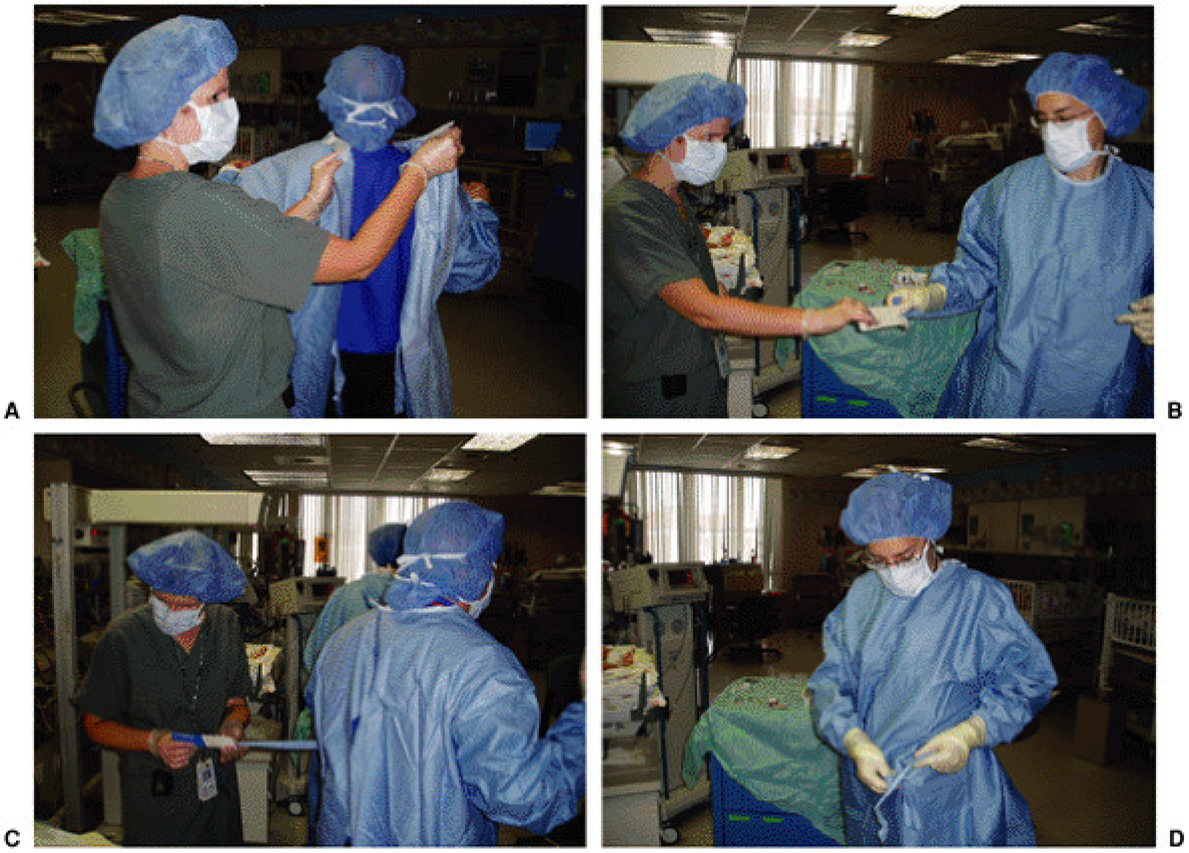

FIG. 4.1. Correct technique for putting on a sterile gown. Operator is assisted into gown. A: The assistant pulls the gown up and back over the operator's shoulders by grasping the inside surface and ties the neck ties at the back of the operator's neck. B: Operator hands tip (protected with a removable cardboard tab) of sterile tie to assistant. C, D: Operator carries the tie around to the front where the operator takes tie (without the cardboard tab) and ties the gown.

H. Complications

- Dry skin with repeated use
- Hexachlorophene
  - Transcutaneous absorption with CNS vacuolation (26,27,28 and 29)
  - Possible teratogenicity when used for hand washing by pregnant staff member (30,31)
- Iodine
  - Burns
  - Allergic contact dermatitis has been reported (32).
  - Skin absorption/hypothyroidism (5,6 and 7)
    - A high incidence of transient neonatal hypothyroidism has been observed in premature infants in Europe after routine skin cleansing with iodine. The same high incidence has not been noted in North America. This difference in incidence may be due to the prior iodine status of the neonate (5).
- Iodophore
  - Burns possible when allowed to pool under infant
  - Absorption through skin reported in burn patients and neonates (6)
  - Alteration of thyroid function (5,7)
- Chlorhexidine
  - Similarity in name and preparation has led to some confusion between chlorhexidine and hexachlorophene. These compounds are different in structure and properties (Table 4.1).
  - Ototoxicity when instilled into middle ear (33)
  - Burns possible when allowed to pool under infant
  - Absorption through skin and from umbilical stump (34,35). No associated pathology was documented.
  - Contamination with gram-negative organisms has been reported, in particular, Pseudomonas and Proteus species (36,37).
  - There is no evidence that the detergent or alcohol preparations are susceptible to contamination.
- Alcohol burns in premature infants (38,39)
- Latex allergy in operators and in infants with neural tube defects (22,23).

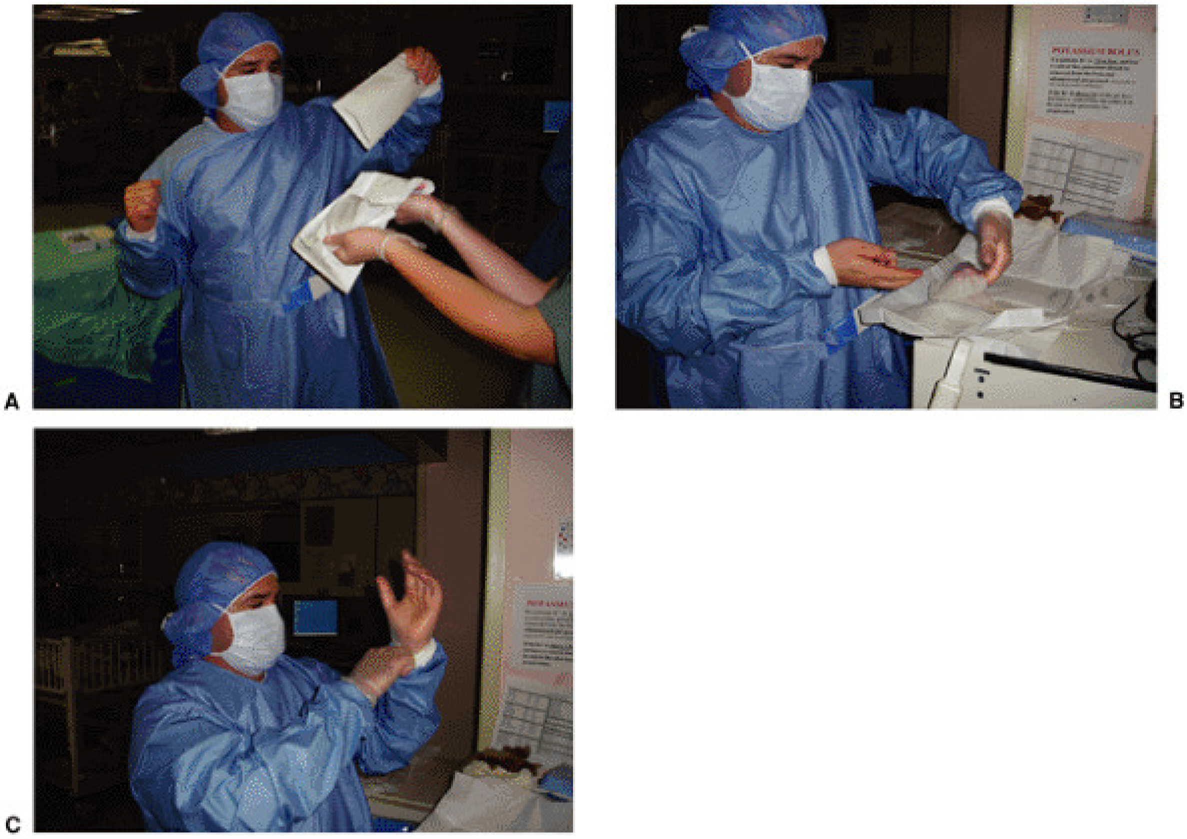

FIG. 4.2. Correct technique for putting on sterile gloves. A: Assistant has opened outer pack, allowing removal of uncontaminated inner pack by operator. B: Correct method for lifting second glove with gloved hand to avoid contact with skin as second glove is pulled up over sleeve ends. C: Pulling first glove up over sleeve ends. The inside surface of the glove is never touched by the gloved hand.

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5-Analgesia and Sedation in the Newborn

Nicholas J. Marsh

A. Introduction

Pain management is an integral part of compassionate neonatal medical care. Historically, barriers to adequate pain management in neonates have been related to the question of pain perception in the newborn. This question is no longer debated, and the use of analgesics for these patients is well established (1,2,3,4 and 5). However, pain management and sedation practices continue to vary among practitioners (6,7). Safe care requires careful choice and dosing of medications, appropriate monitoring, and preparedness to manage complications (4,8). This chapter offers general guidelines for the management of analgesia and sedation in newborn infants.

B. Definitions

- Analgesia: A condition in which nociceptive stimuli are perceived but are not interpreted as pain; usually accompanied by sedation without loss of consciousness (9)
- Conscious sedation: A medically controlled state of depressed consciousness that allows protective reflexes to be maintained, retains the ability to maintain a patent airway independently and continuously, and permits appropriate responses by the patient (8)
- Deep sedation: A medically controlled state of depressed consciousness or unconsciousness from which the patient is not easily aroused. It may be accompanied by a partial or complete loss of protective reflexes and includes the inability to maintain a patent airway independently and respond purposefully to stimulation (8).
- Tolerance: The ability to resist the action of a drug or the requirement for increasing doses of a drug, with time, to achieve a desired effect (10)
- Withdrawal: The development of a substance-specific syndrome that follows the cessation of, or reduction in, intake of a psychoactive substance previously used or administered regularly (11)
- Neonatal abstinence syndrome: Onset of withdrawal symptoms in neonates upon cessation of an agent associated with physical dependence (11)

C. General Indications

- Any condition or procedure known to be painful (4,12) (see E)
- Physiologic indications consistent with perception of pain (1,13)
  - Tachycardia
  - Tachypnea
  - Elevated blood pressure (with secondary increase in intracranial pressure)
  - Decreased arterial oxygen saturation
  - Hyperglycemia secondary to hormonal and metabolic stress responses
- Behavioral indications consistent with perception of pain (4,5,13,14,16)
  - Simple motor responses (i.e., withdrawal of an extremity from a noxious stimulus)
  - Facial expressions (i.e., grimace)
  - Altered cry (primary method of communicating painful stimuli in infancy)
  - Agitation
  -

D. Specific Indications

- Analgesia

  In general, the potency of analgesic treatment selected should be related directly to the anticipated or assessed level of pain (1).

  - Mild pain
    - Nonpharmacologic approaches (see H)
    - Local and/or topical anesthesia
    - Nonopioid analgesics (e.g., acetaminophen)
  - Moderate and severe pain
    - Intravenous opioid analgesics (see E)
    - Local and/or topical anesthesia
    - Benzodiazepines (in combination with D2a; see E)
- Sedation

  Sedatives may be co-administered with analgesics to enhance the anticipated benefits. Because of the escalated risks associated with deep sedation, conscious sedation should be the usual clinical endpoint.

  - Benzodiazepines (see E)
  - Chloral hydrate (see E)
  - Nonpharmacologic approaches (see H)

E. Precautions

- Be aware, when assessing patients, that:
  - The clinical assessment of pain in the newborn is imprecise.
  - Physiologic and behavioral indicators of pain are nonspecific and may be related to many other factors.
  - Intubated neonates receiving muscle relaxants may have altered physiologic indicators and completely ablated behavioral indicators.
  - A high index of suspicion is required to identify newborn infants in pain (13).
- Be aware, when medicating patients, that:
  - There are numerous potential complications associated with analgesic and sedative agents (Table 5.1) (17,18).
  - Large inter- and intraindividual variations in response may occur (19).
  - Medications must always be titrated slowly (4).
  - Co-administration of opioids, benzodiazepines, and other sedatives may result in greatly exaggerated respiratory depressant effects, including apnea (20,21).
- Resuscitation equipment and medications should be immediately available. Be prepared to support ventilation and perform tracheal intubation if needed; respiratory depression is a common side effect of a number of analgesic agents.
- Be aware that:
  - Newborn infants who have developed tolerance to a sedative or analgesic agent, by either direct or in utero exposure, may exhibit symptoms of the neonatal abstinence syndrome upon abrupt cessation or reversal of the administered agent (20,21). For example, naloxone administered to opioid-dependent neonates may precipitate acute, severe withdrawal symptoms (11).
  - Chronic analgesic therapy with agents known to induce tolerance should be weaned gradually, with close monitoring for evidence of withdrawal symptoms (4,20,21).

- When using analgesics for a painful procedure:
    - Consider both the duration and the anticipated pain when selecting medications and methods. For example, short procedures with mild to moderate discomfort, such as lumbar puncture, may be best managed with topical and local anesthetics (22,23 and 24).
    - Minimize the number of painful episodes. Multiple procedures performed at the same time may avoid the need for repeated administration of analgesics (2,15).
    - Ensure that oxygen, suction, airway, resuscitation equipment, and reversal agents are readily available.
    - Follow nothing-by-mouth (NPO) guidelines for ambulatory surgery.
    - Have a nurse, or other professional not involved in the procedure, constantly monitor respirations, pulse oximetry, heart rate, and level of consciousness.
- Chloral hydrate, previously regarded as a highly safe sedative, should be used with caution in neonates (particularly premature neonates) owing to the risk of hyperbilirubinemia and accumulation of toxic metabolites (25,26 and 27). For these reasons, a single dose only is recommended.

F. Advantages and Disadvantages of Commonly Used Agents in the Newborn

See Table 5.1.

G. Complications

See Table 5.1.

H. Nonpharmacologic Approaches

- Swaddling during heel-stick procedures has been shown to reduce behavioral pain responses (28).
- Non-nutritive sucking has been demonstrated to significantly reduce crying in response to painful stimuli (29,30).
- Sucrose
    - Infants who drank 2 mL of a 12% sucrose solution prior to blood collection via heel stick cried 50% less than control infants during the same procedure (30).
    - Infants who received sucrose on a pacifier prior to and during circumcision cried significantly less than control infants (30).
    - 2 mL of 12% to 50% sucrose administered orally 2 minutes prior to the procedure is an effective neonatal analgesic with few adverse effects (31,32).

I. Contraindications

- There are no absolute contraindications to using analgesia and/or sedation when deemed clinically appropriate.
- Be aware of the potential side effects associated with the specific agent selected and take the proper precautions.

TABLE 5.1 Sedative and Analgesic Agents Commonly Used in the Newborn

Agent	Category	Mechanism of Action	Advantages	Disadvantages	Recommended Dose	Metabolism
Acetaminophen	Oral analgesic	Inhibition of peripheral afferent pain signals	No respiratoy depression	Mild analgesia	10â€“20 mg/kg p.o., p.r.	Hepatic
Fentanyl (Sublimaze)	Synthetic narcotic analgesic	Opioid receptor agonist	Rapid onset of action (3â€“5 min) More potent than morphine Reversible with narcotic antagonist	Short duration (30â€“60 min) Respiratory depression Hypotension Risk of seizures Chest wall rigidity with rapid infusion Tolerance and withdrawal	1â€“5 Âµg/kg i.v. bolus 0.5â€“1.5 Âµg/kg/h continuous infusion (analgesia)	Hepatic
Morphine	Narcotic analgesic	Opioid receptor agonist	Longer duration than fentanyl (4 h) Reversible with narcotic antagonist	Slower onset of action than fentanyl (10â€“15 min) Respiratory depression More adverse cardiovascular side effects than fentanyl Tolerance and withdrawal	20 Âµg/kg/h (ventilated patients)	Hepatic
Meperidine (Demerol)	Narcotic analgesic	Opioid receptor agonist	Longer duration than fentanyl (2â€“4 h) Reversible with narcotic antagonist Less respiratory depression than morphine	Slower onset of action than fentanyl (10 min) Tolerance and withdrawal	0.5â€“1.5 mg/kg i.v. or i.m.	Hepatic
Diazepam[a] (Valium)	Benzodiazepine sedative/hypnotic	Brainstem reticular formation depressant	Sedation Music relaxation Rapid onset (1â€“2 min)	No analgesic effect Respiratory depression Hypotension Withdrawal symptoms may occur	0.1â€“0.2 mg/kg i.v.	Hepatic
Lorazepam[a]	Benzodiazepine	Brainstem	Sedation	No analgesic effect	0.05â€“0.1 mg/kg i.v.	Hepatic

(Ativan)	sedative/hypnotic	reticular formation depressant	Longer duration than diazepam (8â€“12 h)	Respiratory depression Hypotension Withdrawal symptoms may occur		
Midazolam[a] (Versed)	Benzodiazepine sedative/hypnotic	Brainstem reticular formation depressant	Sedation Rapid onset of action (2â€“5 min)	No analgesic effect Respiratory depression Hypotension Withdrawal symptoms may occur	0.05â€“0.15 mg/kg i.v. loading dose 0.16â€“1 Âµg/kg/min continuous infusion	Hepatic
Phenobarbital	Barbiturate sedative	Nonspecific CNS depressant	Sedation Long half-life Serum levels easily monitored Reduces serum bilirubin levels	No analgesic effect Slower onset of action than other barbiturates (5 min) No specific antagonist Respiratory depression	2â€“10 mg/kg i.v. i.m., p.o.	Hepatic
Chloral hydrate	Sedative	Central depressant effect	Sedation Minimal cardiorespiratory side effects	No analgesic effects Gastrointestinal irritant May accumulate in neonates May cause myocardial depression Associated with hyperbilirubinemia Toxic metabolites may accumulate with repeated dosing	25â€“50 mg/kg p.o., p.r. One administration onlyâ€”repeated doses increase risk of accumulation and toxicity	Hepatic
EMLA cream (lidocaine 2.5%, prilocaine 2.5% cream)	Topical anesthetic	Delivery of local anesthetic to dermal and epidermal tissue	Painless administration, direct application to intact skin	Not recommended in neonates <1 mo old, contraindicated in patients with congenital or idiopathic methemoglobinemia or those receiving methemoglobininducing agents Systemic absorption of active ingredients with formation of methemoglobinemia	Age 0â€“3 mo: maximum 1 g, 10 cm^2, â‰¤ 1 h Age 3â€“12 mo: maximum 2 g, 20 cm^2, â‰¤ 4 h	Hepatic, renal

Data from refs. 1,2,4,5,13,19,21,26

CNS, central nervous system.

[a] Limited data available in newborns.

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6-Temperature Monitoring

Monisha Bahri

Temperature measurement is an important part of normal newborn care. Accurate measurement is important to detect deviations from normal and also for optimal incubator and radiant warmer function.

The purpose of monitoring temperature is to maintain the infant in a thermoneutral environment zone. This is defined as the narrow range of environmental temperature in which the infant maintains a normal body temperature without increasing metabolic rate and hence oxygen consumption.

Temperature monitoring may be done intermittently or continuously. The site of measurement may be core (rectum, esophagus, or tympanic) or surface (skin, axilla). Currently, the axillary route is preferred, especially for preterm neonates. The various methods are discussed further in this chapter.

Intermittent Temperature Monitoring

A. Equipment

- Mercury-in-glass thermometer
    - Benchmark standard
    - Determination time >3 minutes.
    - Risk of breakage/mercury poisoning from vaporized mercury (1).
    - American Academy of Pediatrics (AAP) recommendation is that mercury thermometers be removed from medical offices, medical facilities, and homes (1).
    - No longer used in neonatal units
- Electronic digital thermometers (Fig. 6.1)
    - Most widely used
    - Thermometer is a small hand-held device.
    - Temperature sensor may be a thermistor or thermocouple.
    - Temperature is sensed by the probe; the signal is then processed electronically and displayed digitally. There is an audible signal at the end of the determination time window.
    - Determination time is <45 seconds.
    - Resolution is 0.1Â°C.
    - Probe-type electronic thermometers are designed to be used with disposable probe covers.
- Infrared electronic thermometry
    - Sensitive infrared sensor detects infrared energy radiation from the tympanic membrane.
    - Sensor converts the infrared signal to an electrical signal.
    - Electrical signal is then processed and displayed digitally as temperature.
    - Determination time is <2 seconds.
    - Designed to be used with disposable sensor head covers.
    - Cost-effective (2)

B. Contraindications

- Rectal measurement in very low-birthweight infants

C. Limitations

- Infrared thermometers have less correlation with glass thermometer measurements than digital disposal or electronic thermometers (2).
- Studies have failed to show adequate correlation between infrared thermometer readings and rectal or axillary measurements in newborns (3,4).
- Readings can vary from axillary site depending on environment (radiant warmer, open crib, or incubator) (5).

D. Precautions

- Probe-type electronic thermometers
  - Always use disposable probe cover.
  - Do not force probe, as perforation can occur, e.g., in rectal measurement.
- Infrared thermometers
  - Always use disposable sensor head covers.
  - Do not force sensor head into the ear canal.
  - Do not use in infants with middle ear disease.
  - Do not use in very low-birthweight infants because of inappropriate speculum size. Sensor head may not be small enough for low-birthweight infants weighing less than 1,000 g.
  - Erroneous readings may result from:
    - Not having the probe lined up with the tympanic membrane
    - The presence of heavy cerumen
    - The presence of serous otitis media (6)

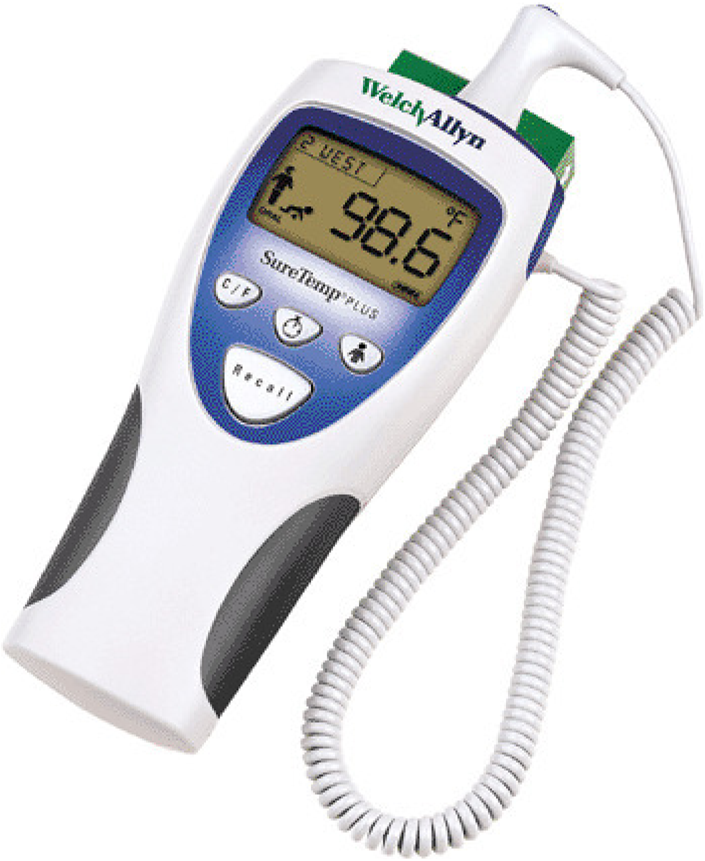

FIG. 6.1. Electronic thermometers: Probe thermometer. (Courtesy of Welch Allyn, New York, USA.)

E. Technique

- Probe-type electronic thermometers
    - Apply disposable probe cover to the probe.
    - For core temperature, insert probe into the rectum (2 to 3 cm).
    - For noninvasive approximation of core temperature, place the probe in the axilla (Fig. 6.2) (7,8 and 9).
    - Hold the probe in place and wait for an audible beep before removing the probe.
    - Read temperature and return the probe to its compartment to deactivate the unit.
- Infrared thermometers
    - Apply disposable cover to the sensor head.
    - Gently insert tapered end into the ear canal.
    - While holding the unit steady, depress trigger.
    - Remove from the ear canal and read temperature.
    - Remove used disposable cover.

F. Complications

- Inaccurate reading (10,11,12 and 13)
- Tissue trauma
    - Rectal or colonic perforation (10,14,15)
    - Pneumoperitoneum (16)
    - Peritonitis

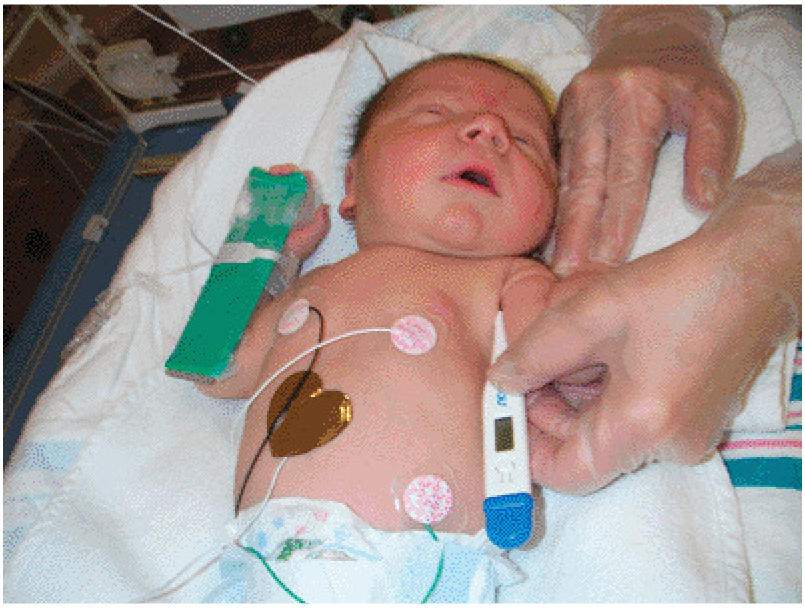

FIG. 6.2. Axillary temperature being taken with electronic probe thermometer. The probe is held perpendicular to the patient, and the arm is held securely against the side of the chest.

- Risk of trauma to the tympanic membrane
- Thermometer housing unit can transmit infection; disinfect after each use.

Continuous Temperature Monitoring

A. Purpose

- Provides reliable continuous monitoring of neonatal body temperature.
- Provides trend of temperature over time.
- Provides automated environmental control (Fig. 6.3).

B. Background

- Sites used may be surface, e.g., skin over the abdomen, or core, e.g., rectum, esophagus.
- Thermistor probes (most widely used)
    - The thermistor is a resistive device, having a high negative temperature coefficient of resistance, so that its resistance decreases proportionately as the temperature increases.
    - As the resistance of the thermistor changes, the electrical current flowing through the probe changes proportionally.
    - The level of current detected by the electronic monitor is converted to thermal units.
- Thermocouple probes
    - The thermocouple probe is a very small bead made up of the junction of two dissimilar metals.
    - The bead generates a very small voltage proportional to temperature.
    - The voltage generated by the bead is measured by the monitor and converted to thermal units.
    - The thermocouple and the thermistor are not interchangeable.
    - Battery-powered interface devices are available that allow the use of thermocouple probes with thermistor-compatible monitors
    - Thermocouple probes are less expensive than thermistors.

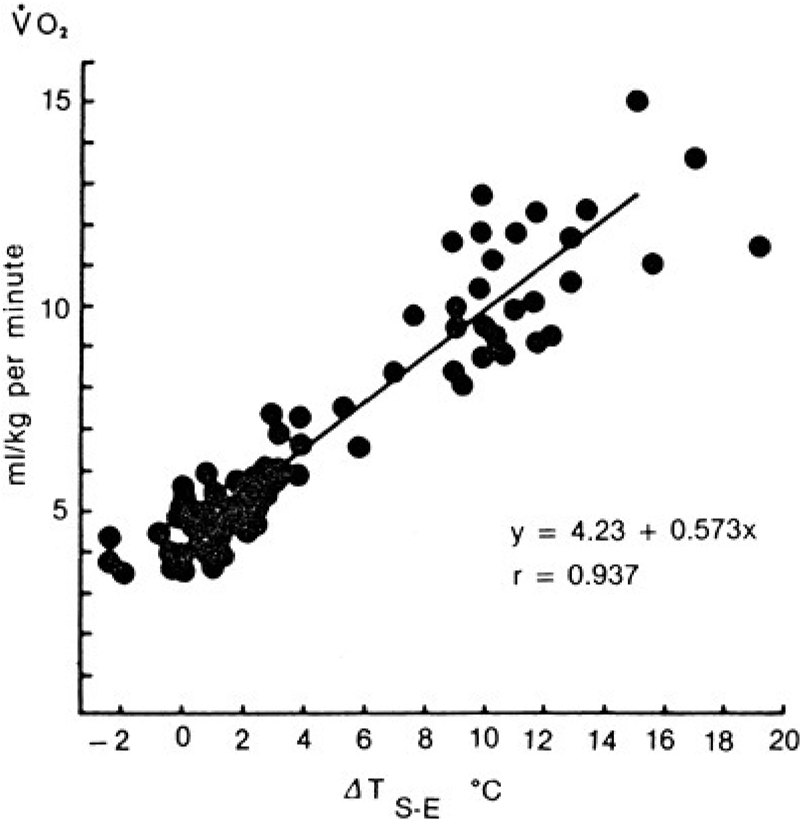

FIG. 6.3. Oxygen consumption as a function of temperature gradient between skin and environment. (From Adamsons K Jr, Gandy GM, James LS. The influence of thermal factors upon oxygen consumption of the newborn human infant. J Pediatr. 1965;66:495, with permission)

C. Indications

- Continuous temperature monitoring for whole-body cooling
- Automatic control of heater output of radiant warmer or incubator

D. Contraindications

- Rectal route in tiny infants

E. Equipment Specifications: Hardware and Consumables

- Continuous temperature monitoring may be a component of the bedside monitor, free-standing, or incorporated into a radiant warmer or incubator.
- Capabilities of the neonatal temperature monitor should include:
  - Resolution to 0.1Â°C
  - Temperature display in both Fahrenheit and centigrade
- Most free-standing temperature monitors are battery-powered.
- The monitors employ a thermistor or thermocouple.
- Monitors using thermistors are identified as YSI 400- or YSI 700-compatible.
  - YSI 400-compatible probes are single-element devices.
  - YSI 700-compatible probes are dual-element devices.
  - YSI 400 and YSI 700 probes are physically identical and are available in the same configurations but are electrically different and will not work interchangeably.
- Monitors using thermocouple probes are identified as such, and the probe connection is different from the thermistor type.

- Probes for both thermistors and thermocouples are available in different configurations for different sites. For example:
    - Surface skin probe
    - Tympanic membrane thermocouple probe

F. Precautions

- Do not apply skin probes to broken or bruised skin.
- Do not apply skin probes over clear plastic dressings.
- Do not use fingernails to remove skin surface probes.
- Do not force core probes during insertion.
- Do not reuse disposable probes.
- Shield skin probe with reflective pad if used with radiant warmer or heat lamp.
- When using servocontrol mechanisms for environmental control, take intermittent temperatures at other sites to monitor effectiveness (17).
- Do not use core temperature to servoregulate the patient's environment (18).

G. Technique

- Skin surface probe (Table 6.1)
    - Prepare the skin using an alcohol pad to ensure good adhesion to the skin.
    - Cover probe with a reflective cover pad (foil-covered foam adhesive pad, incorporated in the disposable probe) (Fig. 6.4). Probe must be covered with an aluminum foil disk to reflect back added heat from devices such as radiant warmers, phototherapy lights, infrared warming lights, and any other external radiant heat-generating sources (19).
    - Apply probe over the liver in the supine infant.
    - Apply probe to the flank in the prone infant.
    - Ensure that skin probe is free of contact with bed (Fig. 6.5).

TABLE 6.1 Site for Temperature Monitoring

Site	Range (Â°C)	Application
Surface		
1. Abdomen over liver	36.0â€“36.5	Servocontrol
2. Axillary	36.5â€“37.0	Noninvasive approximation of core temperature
Core		
1. Sublingual	36.5â€“37.5	Quick reflection of body change
2. Esophageal	36.5â€“37.5	Reliable reflection of changes
3. Rectal	36.5â€“37.5	Slow reflection of changes

- Application of core probe (Table 6.1)
    - Choose probe size according to site, i.e., rectum or esophagus.
    - Esophageal probe
        - Does not need lubrication prior to placement
        - Estimate the length of insertion, using the sum of the distance from the mouth to the tragus of the ear and the distance from the ear to the xiphoid.
        - Insert probe through nostril until the desired length is reached.

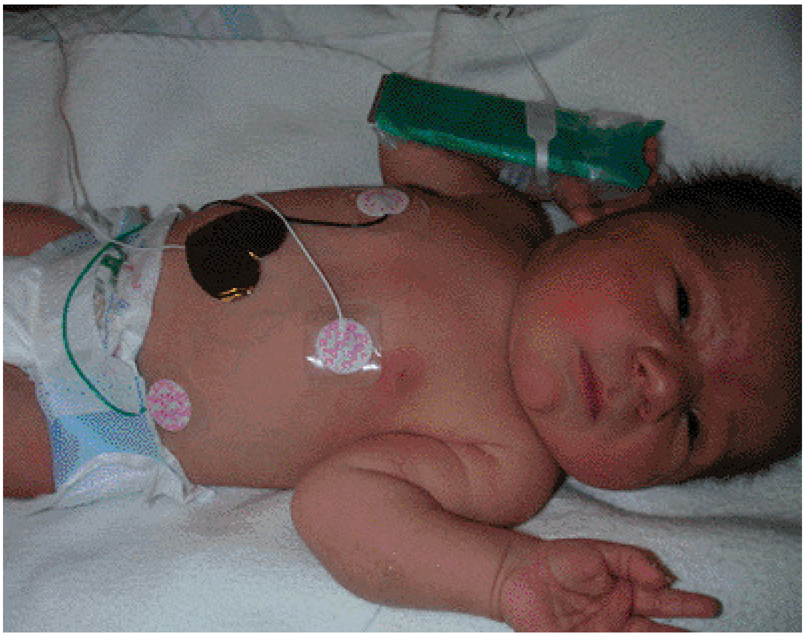

FIG. 6.4. Skin probe properly placed on infant (note that probe has protective foil cover and lies flat on the skin surface).

-
    - Rectal probe
        - Lubricate probe before placing in rectum.
        - Probe should be placed approximately 3 cm beyond anal sphincter; avoid further advancement to avoid risk of perforation.
    - Do not force either probe.
- Connect the probe to the monitor.
- Monitor energy output changes.
- Reposition or replace the probe if temperature recorded does not correlate with that recorded using an electronic thermometer. Skin surface temperature will be cooler than core temperature.

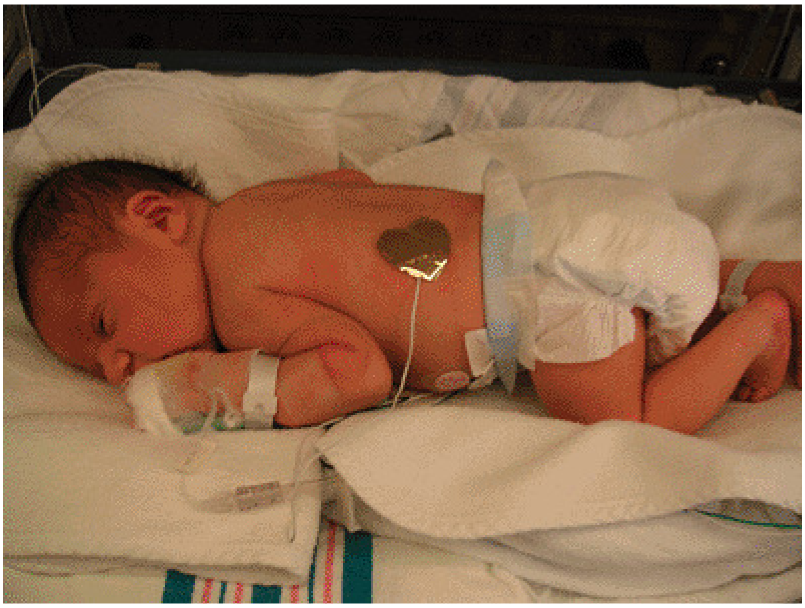

FIG. 6.5. Newborn infant with skin probe free of contact from bed surface.

H. Complications

- Tissue trauma caused by core temperature probe
    - Rectal or colonic perforation
    - Pneumoperitoneum
    - Peritonitis
- Unsafe environmental temperature control caused by unshielded skin probes or loosely adhered probe, when monitoring is used to servoregulate temperature (Table 6.2).

TABLE 6.2 Potential Pitfalls of Servocontrolled Heating Devices

	Skin << Core	**Skin > Core**	**Skin > Core**
Increased heater output	Cold stress Shock (vasoconstricted) Hypoxia Acidosis	Dislodged probe (early) Servo fails to shut off Vasodilators (e.g., tolazoline) Shock (vasodilated)	Dislodged probe (late) Servo fails (late)
Decreased heater output			
Probe uninsulated (radiant heat)			
Servocontrol malfunction			
Onset of fever			
Baby overheated			
Fever			
Internal cold stress (e.g., unheated endotracheal oxygen, exchange transfusion)			

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7-Cardiac/Respiratory Monitoring

Rebecca J. Eick

The monitoring of vital signs in neonates provides an important indicator of overall well-being. Progress in computer technology has facilitated the development of bedside monitors that can integrate multiple monitoring parameters into a single system. This chapter covers the fundamentals of cardiac and respiratory monitoring.

Cardiac Monitoring

A. Purpose

- To provide reliable and accurate monitoring of neonatal cardiac activity
    - Provide trends of heart rate over time

  - Monitor beat-to-beat heart rate variability (1,2)
- To allow assessment and surveillance of critically ill neonates
- To provide early warning of potentially significant changes in heart rate by identification of heart rates above or below preset alarm limits
- To identify bradycardia (with or without associated apnea) in at-risk infants

B. Background

- Electrical activity of the heart is detected using impedance technology through skin surface electrodes (3).
- The low-level electrical signal is amplified and filtered to eliminate interference and artifacts.
- The electrical signal, defined in millivolts, is displayed as an electrocardiogram (ECG) tracing.
- R-wave detection from the QRS complex is used to calculate heart rate.
- The typical three-lead configuration (i.e., leads I, II, III) provides alternative vectors for ECG analysis.

C. Contraindications
None
D. Limitations

- The three-lead ECG is most useful for long-term continuous cardiac monitoring; more detailed cardiac evaluation (i.e., assessment of hypertrophy or axis) or the identification of abnormal cardiac rhythms may require complete 12-lead ECG with rhythm strip.
- Close proximity of electrodes in extremely small infants may cause difficulty with signal detection.

E. Equipment
Hardwareâ€”Specifications

- The monitoring system should have the appropriate frequency response and sensitivity to track the fast and narrow QRS complex of the neonate accurately.
- Heart rate is processed on a beat-to-beat basis with a short updating interval.
- Default heart rate alarm limits should be tailored to the neonatal population.
  - Low heart rate (bradycardia) limit of 100 beats/min (Note: Some term infants may have resting heart rates of 80 to 100 beats/min, requiring lower bradycardia alarm settings.)
  - High heart rate (tachycardia) limit of 175 to 200 beats/min
- Monitor displays
  - Cathode-ray tube (CRT)
    - Has highest resolution and best definition
    - Display can be either color or monochrome
  - Liquid-crystal display (LCD)
    - Flat, thin display monitor
    - Resolution may be suboptimal for fast and narrow QRS complex of neonate
    - Back-lighting is necessary for viewing in low-light environments
    - Unlike with CRT, viewing angle is critical
- Heart rate displayed as alphanumeric part of waveform display or in a separate numerical display window
- Recorder (optional)
  - Electronic memory
    - Real-time ECG
    - Delayed ECGâ€”stored retrospective display used primarily for review of short time interval prior to the occurrence of an alarm
  - Printed record of ECG trend information

    - Typically used to document selected segments of ECG tracings such as periods associated with alarms or abnormal rhythms
    - Monitors may have dedicated printers (often integrated into monitor cases)
    - Central monitoring stations can provide remote access to information from all networked monitor units with printing capabilities.
- Units available for both bedside and transport monitoring (Figs. 7.1 and 7.2)
  - Transport monitors typically smaller and battery-powered
  - Similar capabilities regarding parameter availability, but monitor-specific

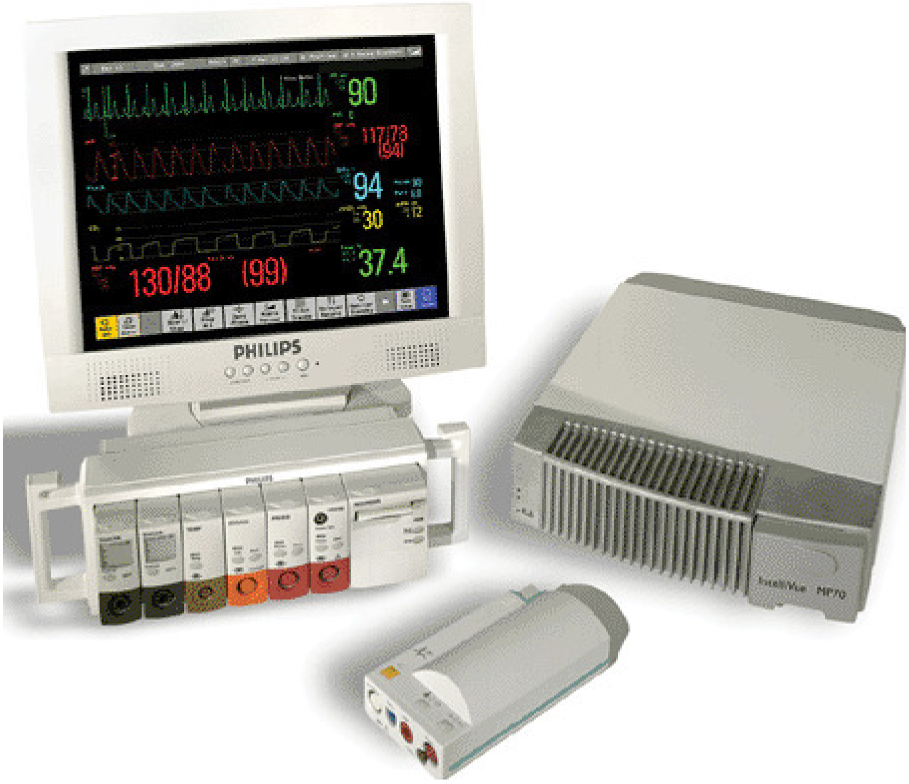

FIG. 7.1. Typical multiparameter neonatal bedside monitor. (Courtesy of Philips Medical Systems.)

Consumablesâ€"Specifications

- Disposable neonatal ECG electrodes
  - Silverâ€"silver chloride electrodes are available in a variety of forms designed specifically for the neonatal population.
    - Patient contact surfaces of electrodes are coated in adhesive electrolyte gel, which acts as conductive medium between the patient and the metal lead while preventing direct patient contact with the metal.
    - Typical commercially available neonatal leads incorporate silverâ€"silver chloride electrodes directly onto paper, foam, or fabric bodies with integrated lead wires.
    - Less commonly, adhesive electrode pads are separate from lead wires, which connect to the electrodes via clips.
    - ECG limb plate electrodes may be used rarely, when the application of chest leads would interfere with resuscitation or the performance of other procedures. Use of electrode gel as a conductor at the skin interface (rather than alcohol pads) is imperative in such cases.
  - Characteristics to consider in electrode selection:
    - Adherence to skin of an active infant
    - Quality of signal attained
    - Minimal skin irritation

        - Ease of removal using water or adhesive remover without damage to or removal of skin
        - Performance in the warm, moist environment of an infant incubator
        - Adhesiveâ€“skin interaction under overhead infant warmers

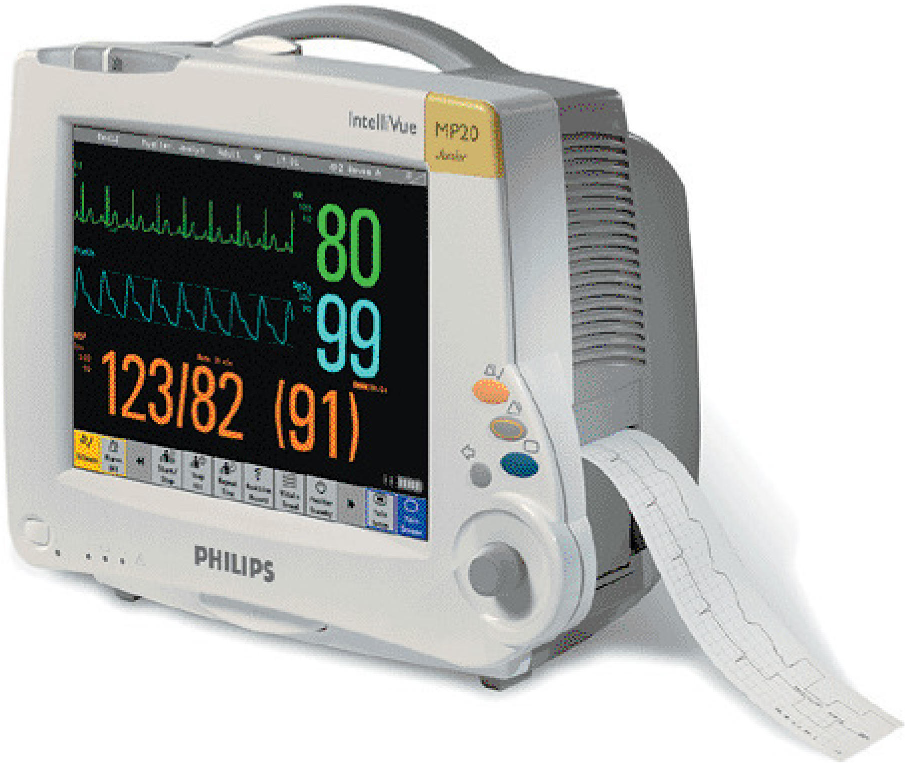

FIG. 7.2. Typical multiparameter neonatal transport monitor with integrated printer. (Courtesy of Philips Medical Systems.)

- Lead wires and patient cable
    - All cables should be clean and the insulation should be free of nicks or cuts.
    - Lead wires should lock or snap into the patient cable, preventing easy disconnections.
    - If using electrodes that attach via clips, use infant/pediatric lead wires with small electrode clipsâ€"standard adult-size clips will place too much torsion on the infant electrode, tugging on the skin and possibly peeling off the electrode.

F. Precautions

- Do not leave alcohol wipes under electrodes as conductors.
- Do not apply electrodes to broken or bruised skin.
- Do not apply electrodes to clear film plastic dressingsâ€"dressing will act as an insulator between the skin and the electrode.
- To avoid skin damage, do not use fingernails to remove electrodes.
- Secure the patient cable to the patient's environment to prevent excessive traction.
- Use only monitors that have been checked for safety and performanceâ€"usually indicated by a dated sticker on the monitor.
- Do not use monitors with defects such as exposed wires, broken or dented casing, broken knobs or controls, or cracked display.
- Monitor alarms should prompt immediate patient assessment.
    - Note alarm indication (i.e., tachycardia or bradycardia).
    - Treat patient condition as necessary or correct the source of any false alarm.

  - If alarm is silenced or deactivated during the course of patient evaluation, it should be reactivated prior to leaving the patient's bedside.

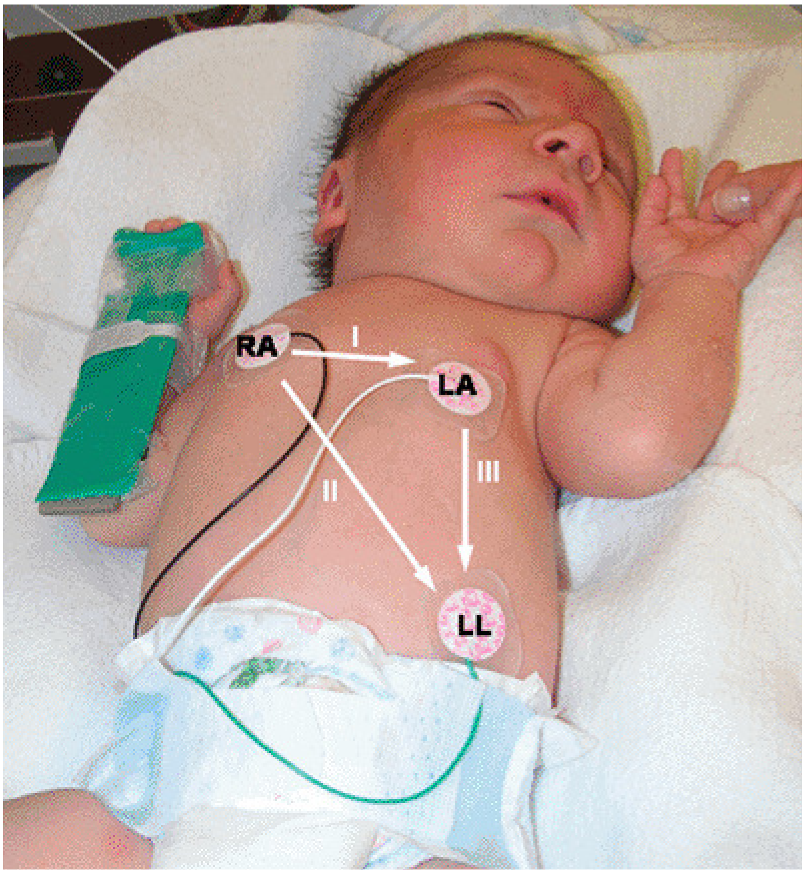

FIG. 7.3. Basic electrode placement and lead vectors for optimal electrocardiogram signal detection. Right arm/left arm positions also provide maximal signal for impedance pneumography.

G. Techniques

- Familiarize yourself with the monitor prior to beginning.
- Electrode and lead wire placement: Although you should refer to the monitor manufacturer's placement instructions, general electrode placement guidelines follow.
  - Skin preparation: Skin should be clean and dry to provide the best electrode-to-skin interface.
    - Wipe skin with an alcohol pad and allow to dry thoroughly.
    - Avoid the use of tape to secure electrodesâ€”for optimal performance and proper electrical interface, electrodes must adhere directly to skin.
  - Basic three-lead configuration for electrode placement (for electrodes with integrated lead wires) (Fig. 7.3)
    - Right arm (white): right lateral chest at level of the nipple line
    - Left arm (black): left lateral chest at level of the nipple line
    - Left leg (red or green): left lower rib cage
    - Although this configuration allows the use of the same electrodes to monitor both ECG and respiration, optimal ECG signal may be obtained when the right arm lead is at the right mid-clavicle and the left leg lead is at the xiphoid (4).
  - If not using electrodes with integrated wires, place electrode pads in basic three-lead configuration as above, then connect lead wires via electrode clips.
    - White lead (right arm) to right chest electrode
    - Black lead (left arm) to left chest electrode
    - Red or green lead (left leg) to left lower rib cage electrode
- Turn monitor onâ€”most monitors will conduct an automatic self-test.

- Connect the patient cable to the monitor.
- Select the lead that provides the best signal and QRS size (lead II is usual default) (Fig 7.4).
    - Ensure that heart rate correlates to QRS complexes seen on displayâ€”make sure that the QRS detector is not counting high or peaked T or P waves.
- Verify that low and high heart rate alarms are set appropriately.

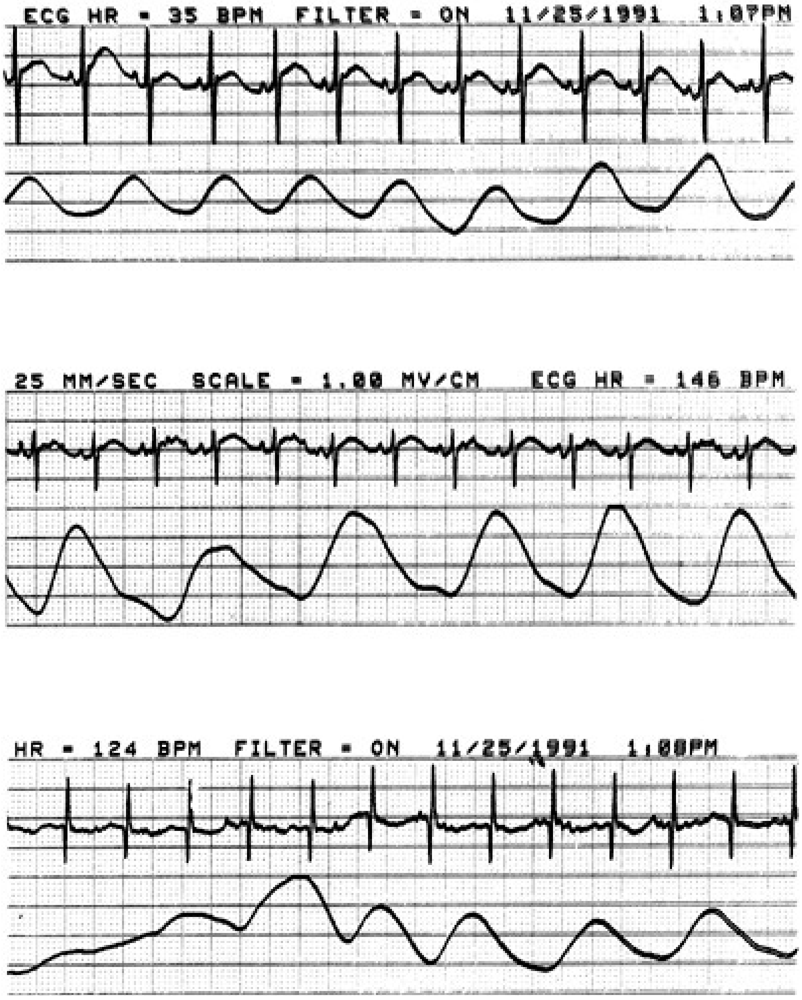
ECG HR = 35 BPM FILTER = ON 11/25/1991 1:07PM
25 MM/SEC SCALE = 1.00 MV/CM ECG HR = 146 BPM
HR = 124 BPM FILTER = ON 11/25/1991 1:08PM

FIG. 7.4. Typical electrocardiogram tracings: lead I (top), lead II (middle), and lead III (bottom).

H. Complications

- Skin lesions (rare)
    - Irritation from alcoholâ€”may occur with even short-term application to immature skin
    - Trauma caused by rubbing with excessive vigor during skin preparation
    - Irritation from incorrectly formulated electrode gel
    - Secondary effects of skin breakdown
        - Cellulitis or abscess formation
        - Increased transepidermal water losses
        - Hypo- or hyperpigmented marks at sites of prior irritation or inflammation (Fig. 7.5)

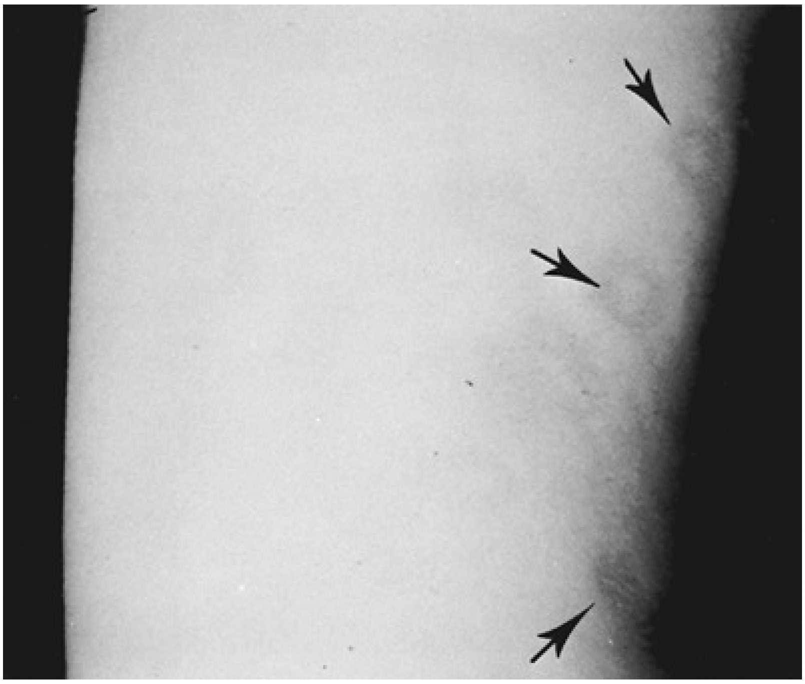

FIG. 7.5. Residual hyperpigmented marks on the extremities present more than 1 year after application of electrocardiogram leads for cardiorespiratory monitoring.

TABLE 7.1 Steps to Minimize Artifact Interference

Problem	**Treatment**
Poor electrode contact/connection	5. Gently clean skin with alcohol wipe and allow to dry prior to electrode reapplication 6. Check electrode/cable connections
Dried electrode	Replace
Equipment interference	7. Systematically turn off one piece of adjacent equipment at a time while observing monitor for improvement in signal quality 8. Once source for interference identified, increase distance between that equipment and patient while rerouting power cords and cables as necessary 9. If above maneuver unsuccessful, replace equipment
60-hertz interference	10. Follow procedure for poor electrode contact 11. Replace patient cable 12. If 1 and 2 unsuccessful, try alternate monitor

- Erroneous readings caused by artifacts (5) (Table 7.1)
  - Electrical interference
    - Sixty-cycle electrical interference (frequency of typical power lines)
    - Interference from other equipment used in the patient's immediate environment
    - Electrical spike may be generated when certain types of polyvinyl chloride tubing are mechanically deformed by infusion pump devicesâ€”spikes appear as ectopic beats on the monitor (rare) (6).
  - Decreased signal amplitude with motion artifact
  - Poor electrode contact or dried electrode gel
  - Incorrect vectors because of inaccurate lead placement (Fig. 7.6)
  - Inappropriate sensitivity settings

- Monitor or cable failure
    - Hardware or software failure
    - Cable disconnection
- Alarm failure
    - False alarms (either tachycardia or bradycardia) resulting from inaccurate interpretation of heart rate
    - Inappropriate alarm parameters for patient

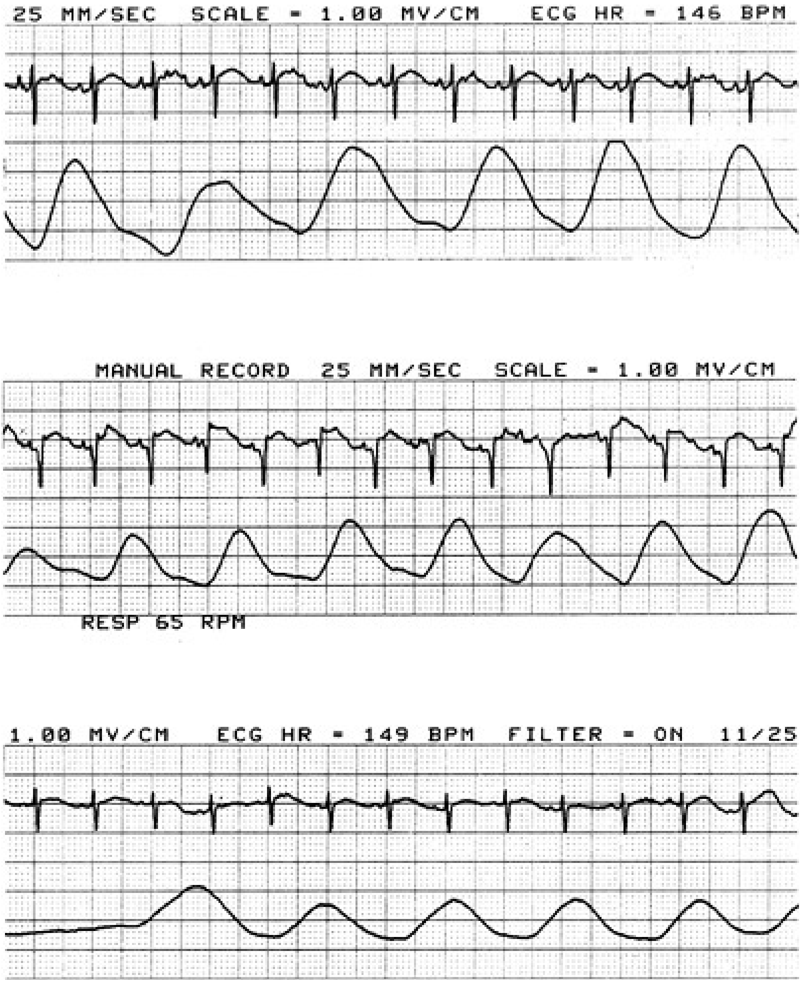
25 MM/SEC SCALE = 1.00 MV/CM ECG HR = 146 BPM
MANUAL RECORD 25 MM/SEC SCALE = 1.00 MV/CM
RESP 65 RPM
1.00 MV/CM ECG HR = 149 BPM FILTER = ON 11/25

FIG. 7.6. Normal P-, QRS-, and T-wave detection. Top: Lead II tracing with electrodes properly placed. Note normal P-, QRS-, and T-wave detection. Middle: Lead II tracing with electrodes close together on anterior chest wall. Note altered QRS- and decreased T-wave amplitude. Bottom: Lead II tracing with electrodes placed lateral on the abdomen. Note decreased wave amplitude and flattened P wave.

Respiratory Monitoring

A. Purpose

- Reliable and accurate monitoring of neonatal respiratory activity
    - Trending of respiratory activity over time
    - Detection of apnea
- Assessment and surveillance of critically ill neonates
- To provide early warning of potentially significant changes in respiratory rate by identifying respiratory rates above or below preset alarm limits

B. Background

- Measurement of transthoracic impedance is the most commonly used method for determining respiratory rate (7).
  - A low-level, high-frequency signal is passed through the patient's chest via surface electrodes.
    - Typically utilizes the same electrodes as are used for cardiac monitoring
    - Signal path usually from right arm (white) to left arm (black) electrodes, although some monitors may use right arm (white) to left leg (red or green) (Fig. 7.7)
  - Impedance to the high-frequency signal is measured.
    - Impedance is the electrical resistance to the signal.
    - Changes in lung inflation cause an alteration in the density of the chest cavity, which is detected as a change in impedance.
    - Changes in impedance modulate a proportional change in the amplitude of the high-frequency signal.
  - The change in impedance, as seen by the modulation of the high-frequency signal, is detected and quantified by the monitor and recorded as breaths per minute.
  - The monitor has an impedance threshold limit below which changes in impedance are not counted as valid respiratory activityâ€”cardiac pumping with associated changes in pulmonary blood flow will also cause changes in thoracic impedance (usually much smaller changes than those associated with respiration).

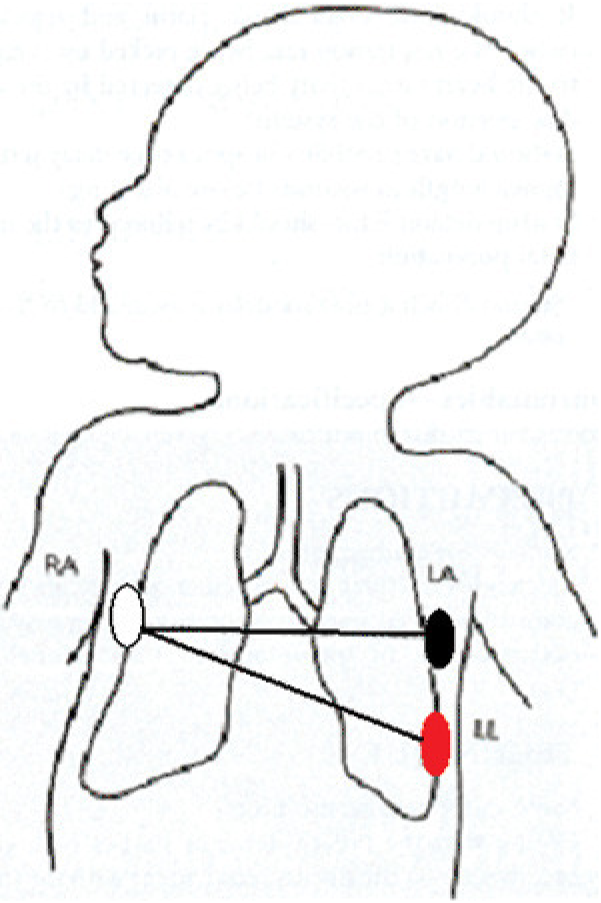

FIG. 7.7. Transthoracic impedance pneumography: diagrammatic representation of the path of the high-frequency signal between chest wall electrodes. Most monitors transmit signal right arm (white) â†’ left arm (black), less commonly right arm (white) â†’ left leg (red).

C. Contraindications

None

D. Equipment

Hardwareâ€”Specifications

- Equipment is the same as that for cardiac monitoring; multiparameter monitors incorporate both cardiac and respiratory monitoring into single units.
- Respiratory monitoring parameters
    - Low-level threshold (for impedance) for breath validation should not be below 0.2 to minimize cardiogenic artifact.
    - Coincidence alarm with rejection applies when respiratory rate being detected is equal to the heart rate activity being detected by the cardiac portion of the system.
    - Default limits should be tailored to the neonatal population.
        - Adjustable apnea time-delay setting (length of apnea in seconds before alarming)
        - Typical apnea time delay is 15 to 20 seconds.

Consumablesâ€”Specifications

- Same as for cardiac monitor

E. Precautions

- Include previously discussed precautions for cardiac monitoring
- Muscular activity may be interpreted as respiration, resulting in failure to alarm during an apneic episode (see G3a following).

F. Technique

- Same as for cardiac monitor
- Ensure that the respiratory waveform correlates to the true initiation of inspiration.
- Move right and left arm electrodes up toward the axillary area if detection of respiration is poor due to shallow breathing.
- Set desired low and high respiratory rate and apnea delay alarm limits.

G. Complications

- Skin lesions (see H1 under Cardiac Monitoring)
- Monitor or cable failure
    - Hardware or software failure
    - Cable disconnection
- Alarm failure
    - False-positive â€œrespiratoryâ€□ signal in the absence of effective ventilation
        - Chest wall movement with airway obstruction (obstructive apnea)
        - Nonrespiratory muscular action (i.e., stretching, seizure, or hiccups) producing motion artifact (Fig 7.8)
    - False apnea alarm despite normal respiratory activity
        - Improper sensitivity not detecting present respiratory activity
        - Incorrect electrode placement
        - Loose electrodes
    - Inappropriate alarm parameters for patient
- Accurate assessment of respiratory rate not practical when using high-frequency ventilatory modes

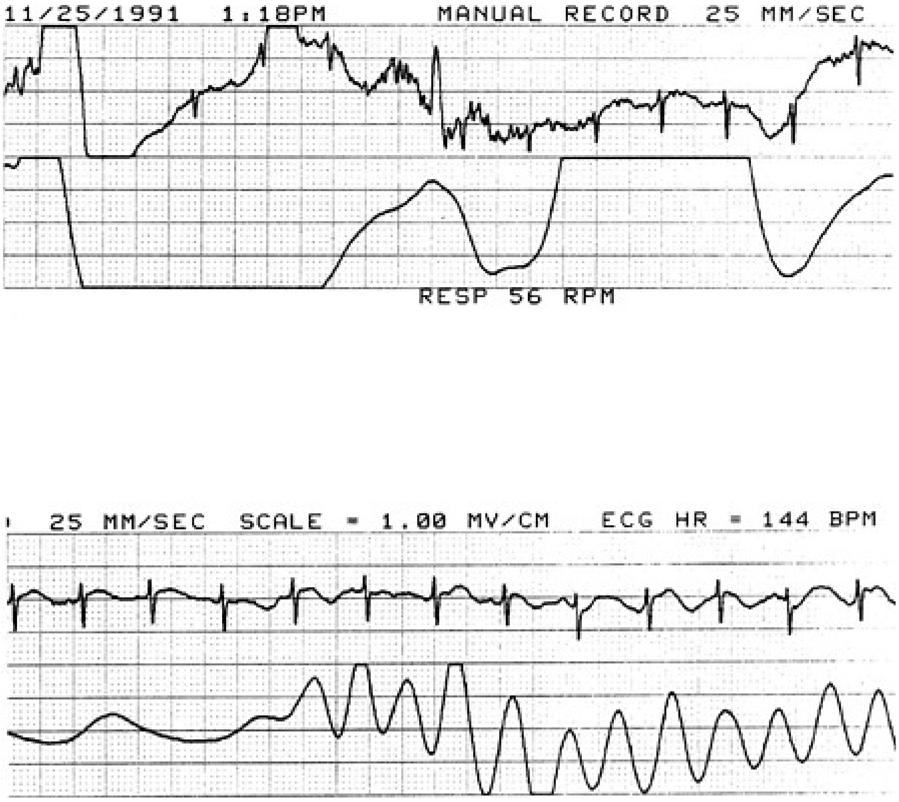
11/25/1991 1:18PM MANUAL RECORD 25 MM/SEC
RESP 56 RPM
25 MM/SEC SCALE = 1.00 MV/CM ECG HR = 144 BPM

FIG. 7.8. Tracings of artifacts affecting electrocardiogram/ respiratory tracings. Top: Loose electrode affected by motion. Bottom: Motion artifact caused by patient's moving arm coming in contact with chest electrodes (note change in respiratory frequency signal).

Cardiorespirograph Monitoring

A. Definition

- Graphical representation of heart rate and respiratory rate over time

B. Purpose

- Monitoring of infants for identification and quantification of heart rate and respiratory activity, with detection of apnea, periodic breathing, and bradycardia
- Identification of chronologic relationships between bradycardia and apnea
- Many systems also provide continuous S_aO_2 information to allow correlation with desaturation events.

C. Background

- Heart rate is plotted graphically as beats per minute (Y axis) versus time (X axis).
- Respiratory waveform is compressed to allow display of time range.
- Short-term trending allows constant updating as the oldest information is displaced (typically based on a 2-minute window of time).
- Time relationship between heart rate and respiratory activity is maintained.
  - Allows for visualization of entire apneic episodes and identification of precipitating factors (e.g., a drop in respiratory rate may precede bradycardia)

- Inclusion of $S_aO_2$allows identification of temporal relationship for desaturation events (S_aO_2 is plotted in the same fashion as the heart rate on a second Y axis)

D. Contraindications
None
E. Equipment
Standard features of most neonatal monitors

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8-Blood Pressure Monitoring

M. Kabir Abubakar

Accurate monitoring of blood pressure is essential for the optimal management of ill infants. Blood pressure is one of the most frequently measured physiologic parameters to evaluate clinical stability in critical care. The recognition and treatment of abnormal blood pressure states has significant prognostic implications in neonatal intensive care (1).
Noninvasive (Indirect) Methods
There are two types of noninvasive blood pressure measurements: auscultatory measurement (manual noninvasive) and oscillatory arterial blood pressure measurement (automatic noninvasive).
Auscultatory Measurement (Manual Noninvasive)
Manual noninvasive auscultatory measurement employs the sphygmomanometer, which is simple, inexpensive, and allows for intermittent blood pressure measurements.
A. Background

- This technique employs a blood pressure cuff, insufflator, manometer, and stethoscope.
- The sphygmomanometer uses a pneumatic cuff to encircle the upper arm or leg and a pressure gauge (manometer) to register the pressure in the cuff.
- There are two types of manometers:
  - Mercury (mercury column)
  - Aneroid (mechanical air gauge)
- The encircling pneumatic cuff is inflated to a pressure higher than the systolic pressure in the underlying artery. The cuff pressure compresses the artery and stops blood flow.

- A stethoscope placed distal to the cuff, over the occluded artery, will pick up the Korotkoff sounds as the pressure of the cuff is decreased to the point at which blood flow resumes through the artery.

  Korotkoff sounds are the noise generated by blood spurting from the compressed artery, producing turbulence and vibration within the vessel.

- As the pressure in the cuff is reduced from above the systolic pressure, five characteristic Korotkoff sounds are heard:
    - Korotkoff I is a sharp thud.
    - Korotkoff II is a loud blowing sound.
    - Korotkoff III is a soft thud.
    - Korotkoff IV is a soft blowing sound.
    - Korotkoff V is silence.
- An 8- to 9-MHz Doppler device can be used in place of a stethoscope. This device will detect only systolic blood pressure levels.

B. Indications

- Measurement of blood pressure in stable infants or when invasive blood pressure measurement is not required or unavailable
- When only intermittent blood pressure measurements are required

C. Contraindications

- Profound edema in the limb to be measured; will affect result
- Decreased perfusion, ischemia, or infiltrate in limb
- Peripheral venous/arterial line in limb

D. Limitations

- Provides only intermittent blood pressure measurements
- Manual measurement cumbersome in small infants
- Accuracy depends on ability to recognize Korotkoff sounds and may be user-dependent
- Pressure may not be detectable in low perfusion state or shock. Do not assume that it is simply an equipment problem; use clinical correlation.
- Pressure is not detectable or is inaccurate in neonates experiencing convulsions or tremors.
- Measures only systolic and diastolic blood pressure; mean blood pressure measurement not available
- Can be used only to measure pressure in the upper arm or thigh
- Inaccurate measurements (Table 8.1)
    - Defective manometer
    - Air leaks at the tubing connections or from dry, rotted tubing
    - Inappropriate cuff size
    - Cuff applied loosely
    - Rapid deflation of cuff
    - Active or agitated patient

TABLE 8.1 Sources of Error in Indirect Blood Pressure Measurements

Problem	Effect on Blood Pressure	Precaution
Defective manometer	***Falsely low values***	1. Check level of mercury at zero cuff pressure
1. Air leaks		
2. Improper valve function		2. Check for cleared definition of meniscus
3. Dry, rotted tubing		3. Verify that pressure holds when tightened
4. Loss of mercury		

D. Vessels Amenable to Central Venous Access

Table 31.1 lists the sites usually used for central venous catheterization in the newborn. When venous access is extremely difficult because of superior vena cava or inferior vena cava occlusion, alternative sites such as the azygos system or the hepatic vein may be used for prolonged access, but there is little information about these approaches in neonates (5, 6).

E. Position of Catheter Tip (Fig. 31.1)

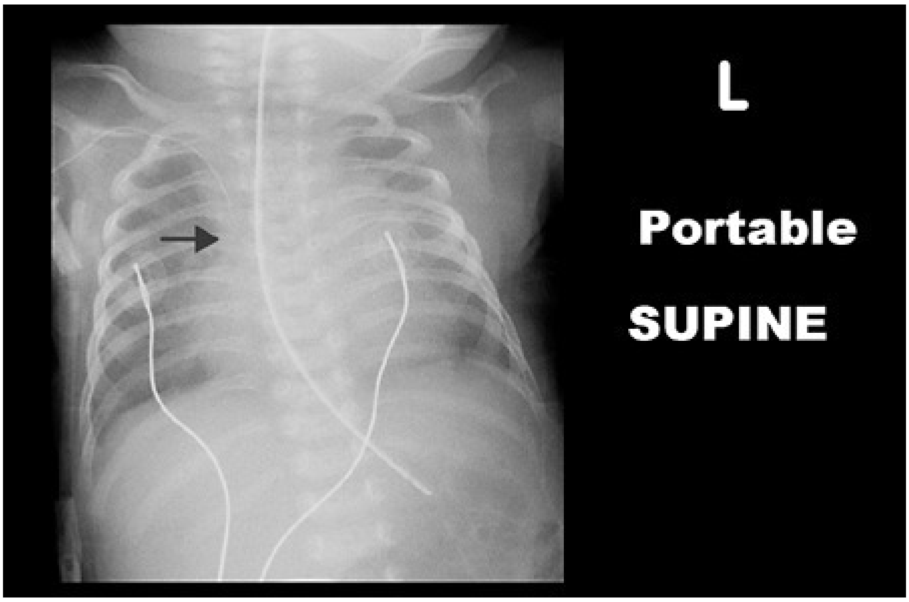

FIG. 31.1. Chest radiograph with PICC tip in appropriate position, just above junction of superior vena cava and right atrium.

- The catheter should be placed in as large a vein as possible, ideally outside the heart, and parallel with the long axis of the vein such that the tip does not abut the vein or heart wall (7). The recommendations for appropriate position of a central venous catheter tip vary, but there is general agreement that the tip should not be within the right atrium (8, 9, 10, 11). However, one large retrospective audit of 2,186 catheters showed that catheters with their tips in the right atrium and not coiled were not associated with pericardial effusions (2).

  Recommendations for appropriate position of the catheter tip are as follows.

    - The catheter tip should be within the superior or inferior vena cava, outside the pericardial reflection, a distance estimated to be about 1 cm outside the cardiac silhouette in preterm neonates and 2 cm outside the cardiac silhouette in term neonates (8).
    - When inserted from the upper extremity, the catheter tip should be in the superior vena cava, outside the cardiac reflection and above the T2 vertebra (12).
    - When inserted from the lower extremity, the catheter tip should be above the L4/ L5 vertebrae or the iliac crest, but not in the heart (12).
    - The tip of the catheter should be at the junction of the vena cava and the right atrium (7, 13).
- Confirmation of catheter tip placement
    - The tip of the radio-opaque catheter is usually seen on a routine chest radiograph (Fig. 31.1), but there can be significant interobserver variability in assessing the position (14). Digital enhancement of the radiograph may improve visualization but does not prevent interobserver variability (15).

  - Two radiographic views (anteroposterior and lateral) help to confirm that the catheter is in a central vein. This is particularly important for catheters placed in a lower extremity, where the catheter may inadvertently be in an ascending lumbar vein and may appear to be in good position on an anteroposterior view (16).
  - The use of radio-opaque contrast improves localization of the catheter tip, particularly when the catheter is difficult to see on a standard radiograph (17, 18). A 0.5-mL aliquot of 0.9% saline is instilled into the catheter to check patency, followed by 0.5 mL of iohexol. The radiograph is taken, and the line is flushed again with 0.5 mL of 0.9% saline. With this technique, there is no need to inject the contrast material while the radiograph is being taken (17). Other authors recommend injecting a 2-mL bolus of nonionic water-soluble contrast medium into the catheter during radiographic exposure, but this technique results in a larger volume of iodine-containing contrast being injected (18).
  - Ultrasonography may also be useful in localizing the catheter tip (19).
  - Chest radiographs obtained for any reason should be scrutinized for appropriate catheter position. Routine weekly radiographs taken for this purpose do not appear to reduce the risk of complications (13).

F. Methods of Vascular Access

- Percutaneous technique
  - Advantages
    - Simpler to perform and relatively rapid procedure
    - May not require sedation
    - Vessel is not ligated as in open cutdown methods
    - Decreased potential for wound infection/dehiscence complications
  - Disadvantages
    - Beyond the initial insertion into the peripheral vein, further passage of the catheter into its final position is essentially a blind technique.
    - Smaller-caliber catheter may preclude use for blood transfusions
    - Potential for injury to adjacent anatomic structures (20)
- Cutdown or open surgical technique
  - Advantages
    - Allows for insertion of larger silicone catheter (3- or 4.2-French [Fr])
    - The catheters can be tunneled under the skin away from the venotomy site, so they can remain in place longer with a lower risk of infection.
  - Disadvantages
    - Requires general anesthesia/intravenous sedation
    - Requires surgical incision
    - Vein is often ligated, so it cannot be reused in the future.
    - Potential for injury to adjacent anatomical structures
    - Increased potential for wound infection
    - An operating room is the ideal setting for the procedure, so risks of transport of critically ill neonates need to be taken into consideration.

G. Types of Central Venous Catheters

TABLE 31.2 Catheter Materials

Type of Catheter	Advantages	Disadvantages
Silicone	Soft, pliable Lower risk of vessel perforation Reported to be thromboresistant	May be more difficult to insert percutaneously Thrombosis reported Fragile material: less tolerance to pressure Poor tensile strength: can tear or rupture May be less radio-opaque
Polyurethane	Easier to insert percutaneously Stiffer on insertion but softens within body Some catheters are more radio-opaque Tensile strength: more tolerant to pressure Reported to be thromboresistant	Increased risk of vessel perforation during insertion Thrombosis reported
Polyethylene	Easier to insert Very high tensile strength	High degree of stiffness may increase vessel perforation during insertion or throughout catheter dwell
Polyvinyl chloride (PVC)	Easier to insert percutaneously Stiff on insertion but softens within body	May leach plasticizers into body High incidence of thrombosis

- Catheter materials: See Table 31.2.
- Types of catheters
  - Percutaneous (PICC) catheters/introducers

    PICC catheters and kits are available commercially. PICCs are generally made of silicone or polyurethane. Sizes include 1.2, 1.9, 2, and 3 Fr. Larger sizes are generally not used in the neonatal population. Most catheters are single-lumen. Recently, a 1.9-Fr double-lumen catheter has become available. Double-lumen catheters can decrease the need for maintaining concurrent IV access when more than one site is required. PICC introducers/needles are available in 19, 20, 22, and 24 gauge. Choice will depend on the size of the vein to be cannulated.

  - Surgically placed central venous catheters

    Surgically placed central venous catheters for neonates are available in sizes 2.5, 2.7, 3, 4.2, and 5 Fr. Catheters are usually silicone or polyurethane, with tissue in-growth cuffs that adhere to the subcutaneous tract, anchoring the catheter. Recently, antimicrobial cuffs have become available. Most catheters are single-lumen, but a few manufacturers make double-lumen catheters in sizes 5 Fr and larger.

Percutaneous Central Venous Catheterization (See Procedure DVD for Video)

A. Insertion sites (Fig. 13.1)

- Antecubital veins: basilic and cephalic veins
- Scalp veins: temporal and posterior auricular veins

- Saphenous veins
- Axillary vein
- External jugular vein

  Right-sided and basilic veins are preferred because of the shorter and more direct route to the central vein. The cephalic vein may be more difficult to thread to the central position because of narrowing of the vessel as it enters the deltopectoral groove and the acute angle at which it joins the subclavian vein. The axillary and external jugular veins are the last choices because they are close to arteries and nerves.

B. Insertion Variations

- Breakaway needle: Needle is inserted into the vein. Next, the catheter is advanced through the needle. The needle is then retracted, split, and removed (Fig. 31.2). Disadvantage: There is a potential for shearing or severing the catheter if it is retracted while the needle is in the vein.
- Peel-away introducer: A needle introducer is used to place a small cannula or sheath into the vein. The needle is then removed and the catheter is threaded through the cannula. The introducer cannula or sheath is then retracted from the vein, split or â€œpeeledâ€□ apart, and removed from the catheter (Fig. 31.3).
- Intact cannula: This technique is now rarely used because most commercially available catheters have a hub and introducer needles. A regular IV cannula is used to obtain venous access. The needle is removed. The catheter is threaded through the cannula to its final position. The cannula is then retracted and slipped off the end of the â€œhublessâ€□ catheter. A blunt needle with hub is connected to the end of the catheter (Fig. 31.4). Disadvantage: The blunt needle attachment must be secured well, otherwise leakage can occur.

C. Placement of PICC Using the Break-Away or Peel-Away Introducer Needle

- Equipment

  All equipment used, except the mask, head cover, and tape measure, must be sterile. Commercial kits contain many of the necessary items.

  - Radio-opaque central venous catheter
  - Break-away or peel-away needle introducer
  - Tourniquet (optional)
  - Drapes
  - Forceps
  - Gauze pads
  - Skin prep: 10% povidoneâ€“iodine or 0.5% chlorhexidine solution (as per institutional policy)
  - Transparent dressing
  - Sterile tape strips
  - Sterile heparinized saline solution (1 U of heparin/mL or per institutional policy)
  - 5- to 10-mL syringe with needle
  - Tape measure
  - Sterile surgical gown, sterile gloves, mask, and head cover
- Preparation
  - Although anesthesia is not required, nonpharmacologic comfort measures, pain medication, or sedation should be provided as needed. A small dose of sedative or narcotic analgesic may be useful.
  - Gather supplies. Wash hands thoroughly.

- Identify appropriate vein for insertion (see D).
- Position infant to facilitate insertion (Table 31.3). Restrain infant; provide comfort measures.
- Measure approximate distance from the insertion site to the point where the catheter tip will be placed (Table 31.3).
- Don mask and cap, scrub hands, and don sterile surgical gown and gloves.
- Trimming of the catheter to appropriate size is based on unit policy and manufacturer recommendations. Catheter is fragile. Handle it with care: Do not clamp or suture, and do not stretch or apply tension to catheter.
- Utilizing sterile technique, flush catheter with heparinized saline solution, leaving syringe attached. A small-barreled syringe (such as a 1-mL syringe) may generate too much pressure, resulting in catheter rupture (21).
- Prepare sterile field: Place drape under extremity. Utilizing the prep solution, prepare the area at and around the insertion site, working outward in concentric circles. Allow the prep solution to dry. Repeat process with new gauze/prep solution. Drape prepared area, leaving insertion site exposed.

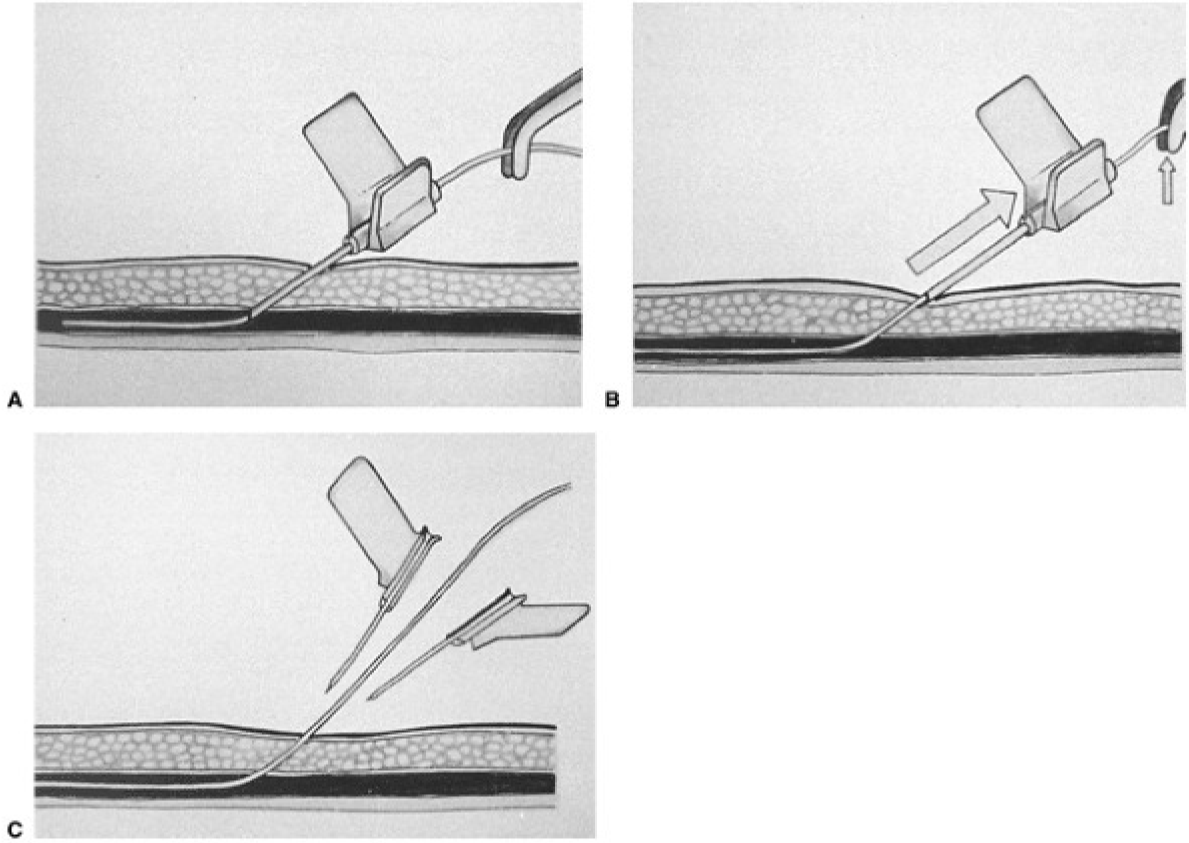

FIG. 31.2. Peripherally inserted central catheter using break-away needle technique. (From Gesco International, San Antonio, TX, USA, with permission.)

- Catheter insertion
  - Utilizing a break-away needle (Fig. 31.2)
    - Apply tourniquet (optional).
    - Providing slight skin traction, insert needle about 1 cm below the intended vein. Insert needle at a low angle (approximately 15 to 30 degrees).
    - When a flashback is obtained, advance the needle about 1/4 in at a lower angle to ensure that the whole bevel of the needle is within the vein.

- Using nontoothed iris forceps, gently grasp the catheter about 1 cm from its distal end and insert it into the introducer needle.

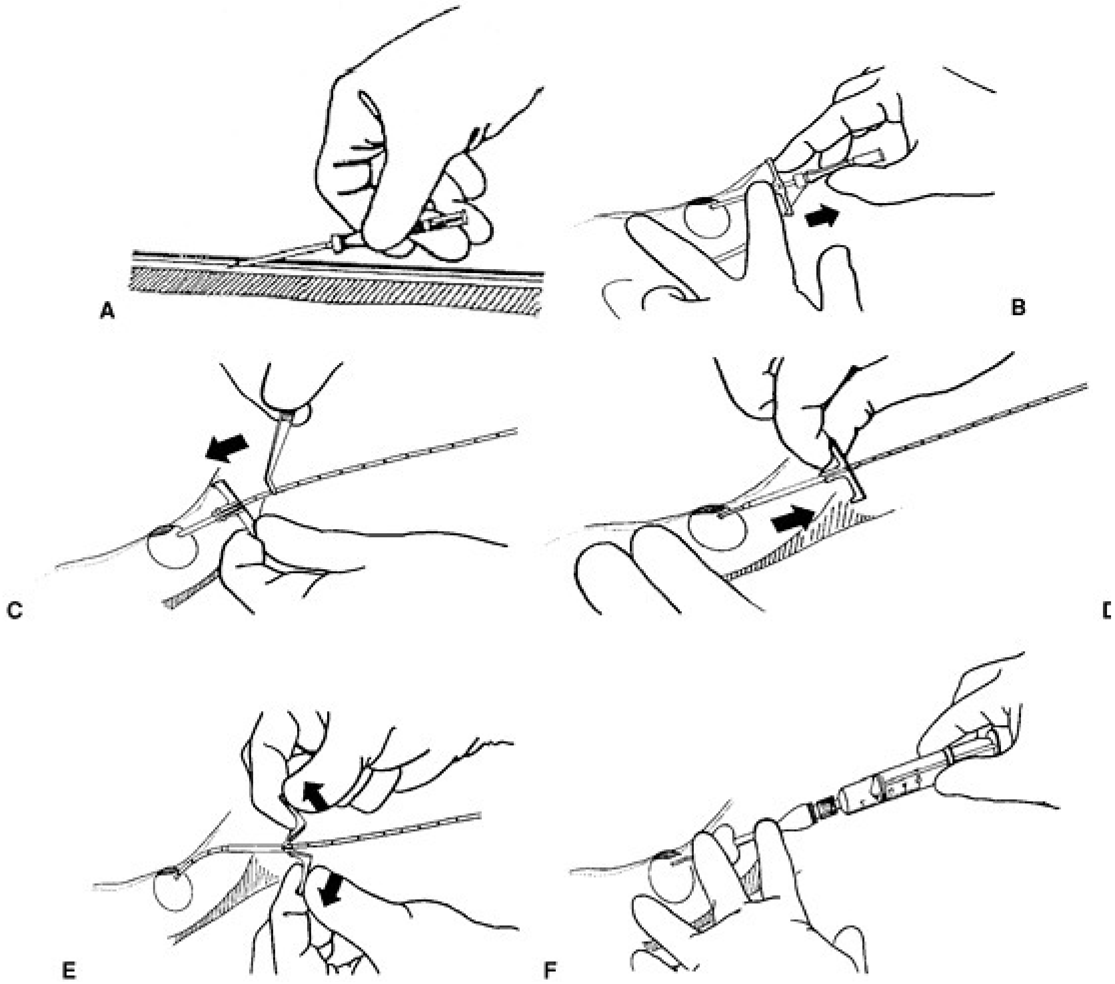

FIG. 31.3. Peripherally inserted central catheter using a peel-away cannula introducer. A: Perform venipuncture. When flashback of blood is noted, reduce angle and advance introducer sheath farther to ensure placement in the vein. B: Withdraw the introducer needle from the sheath. Note that the introducer sheath is supported to avoid displacement. C: Insert the catheter into the introducer sheath using fine nontoothed forceps. D: Withdraw the introducer sheath. Note that the catheter is stabilized by applying digital pressure to the vein distal to the introducer sheath. E: Remove the introducer sheath by splitting and peeling it away from the catheter. Complete catheter advancement to premeasured length. F: Aspirate catheter to check for blood return and flush with heparinized saline to ensure patency. (From Klein C. NeoPicc: The Neonatal and Pediatric Workshop Manual. San Antonio, TX: Klein Baker Medical, 1998, with permission.)

- Caution: Never advance the needle or retract the catheter after inserting it into the needle; the catheter may be severed by this action.
- If a tourniquet was applied, it should be loosened or removed prior to advancement.
- With small, gentle nudges, a few millimeters at a time, advance the catheter through the needle to a distance of about 5 or 6 cm into the vein.

- Once the catheter is successfully advanced to about 5 or 6 cm, withdraw the needle carefully.

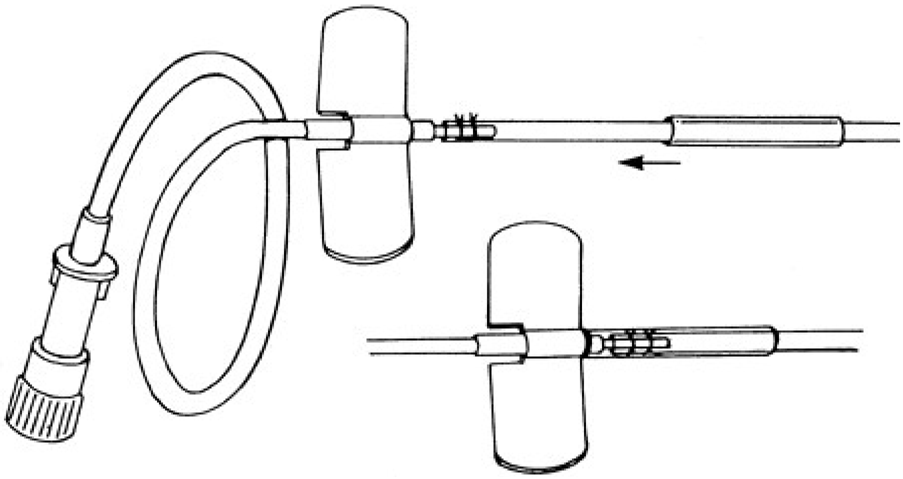

FIG. 31.4. Use of a blunt scalp vein needle to form a hub for a silicone catheter. The plastic needle cover is used to stabilize the needleâ€"catheter junction. A commercially available blunt needle adapter may be inserted and fixed in a similar manner.

- To withdraw the needle, stabilize the catheter by applying gentle pressure over the vein proximal to the needle. Slowly withdraw the introducer needle until it is completely away from the site.
- Break the introducer needle by splitting the wings, and then carefully peel it away from the catheter.
- Continue to advance the catheter into the vein to the premeasured length, by nudging it farther, a few millimeters at a time, using the fine forceps.
- Difficulties in advancing catheter: Gently massage the vein in the direction of blood flow, proximal to the insertion site, or gently flush the catheter intermittently with 0.5 to 1.0 mL of heparinized saline; reposition the arm or head.
- Aspirate to visualize blood return in the catheter, and flush with 0.5 to 1 mL of heparinized saline to clear the catheter.
- Verify length of catheter inserted and adjust as necessary.
- Apply gentle pressure on insertion site with gauze pad to stop any bleeding.
- Secure catheter at skin insertion site with sterile tape strips and cover with sterile gauze until radiographic confirmation of position.

TABLE 31.3 Patient Position and Measurement for PICC Insertion

Site of Insertion	Position of Baby	Measurement
Antecubital veins	Supine, abduct arm 90 degrees from trunk; turn head toward insertion site to prevent catheter from traveling cephalad through ipsilateral jugular vein	From planned insertion site, along venous pathway, to suprasternal notch, to third RICS
Saphenous or popliteal veins	Supine for greater saphenous vein, prone for small saphenous or popliteal; extend leg	From planned insertion site, along venous pathway, to xiphoid process
Scalp veins	Supine, turn head to side; may have to turn head to midline during procedure to assit advancement of catheter	Follow approximate venous pathway from planned insertion site near ear, to jugular vein, right SC joint, to third RICS
External jugular vein	Supine, turn head to side; place roll under neck to cause mild hyperextension	From planned insertion site, to right SC joint, to third RICS
Axillary vein	Supine, externally rotate and abduct arm 120 degrees, flex forearm and place baby's hand behind head; vein is found above artery between medial side of humeral head and small tuberosity of the humerus	From planned insertion site, to right SC joint, to thirt RICS

PICC, peripherally inserted central catheter; RICS, right intercostal space; SC, sternoclavicular.

- Utilizing a peel-away cannula/introducer sheath (Figs. 31.3 and 31.5)

  The procedure is similar to using a break-away needle.

  - Apply tourniquet (optional).
  - Providing slight skin traction, insert needle about 1 cm below the intended vein. Insert needle at a low angle (approximately 15 to 30 degrees).

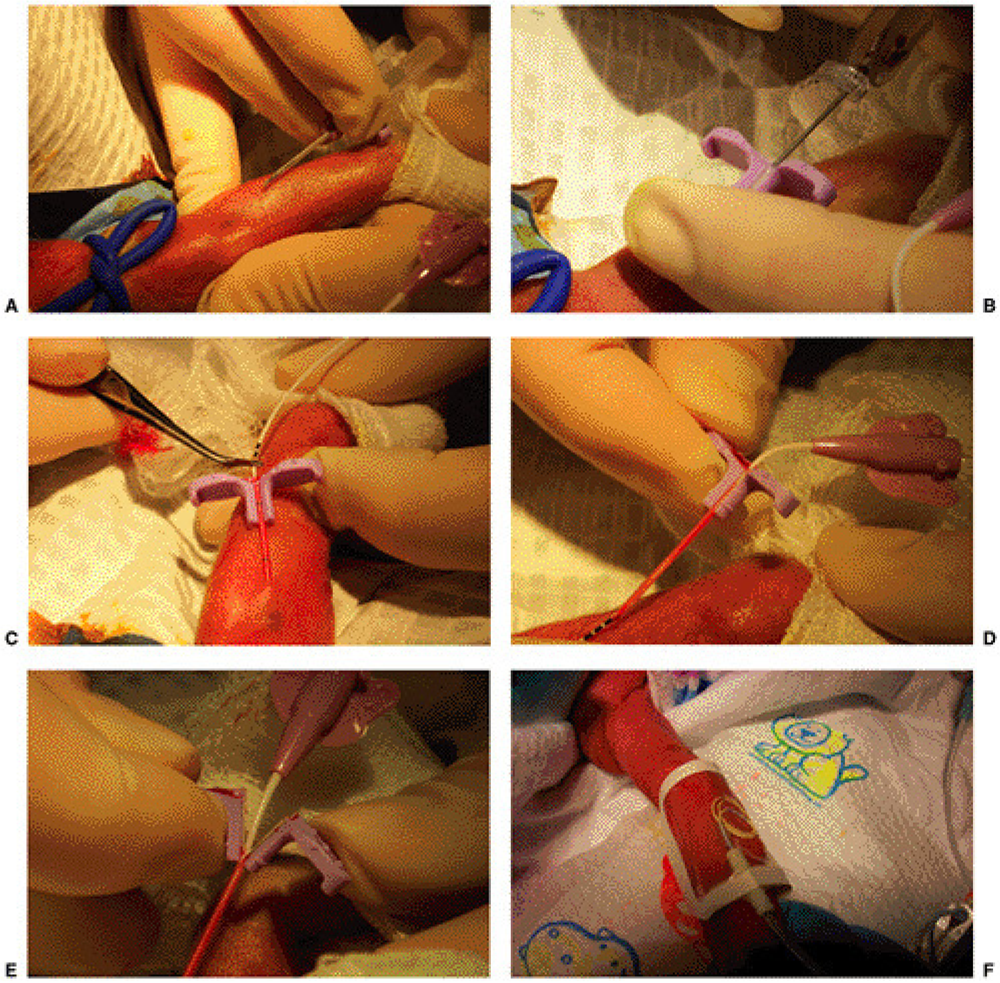

FIG. 31.5. A: Venipuncture with peel-away cannula introducer. B: Withdraw the introducer needle from the sheath. Note that the introducer sheath is supported to avoid displacement. C: Insert the catheter into the introducer sheath using fine nontoothed forceps. D: Withdraw the introducer sheath. E: Remove the introducer sheath by splitting and peeling it away from the catheter. F: Transparent dressing on PICC catheter. Note that the excess catheter length has been coiled in place under the dressing.

- When flashback is obtained, advance the introducer sheath about 1/4 in at a lower angle to ensure that the tip is within the vein.
- Withdraw the introducer needle while leaving the introducer sheath in place. Successful venipuncture is indicated by the flow of blood from the end of the sheath. Apply gentle pressure over insertion site to minimize blood loss. If a tourniquet was applied, it may be loosened or removed at this stage.
- Caution: Do not reintroduce the needle into the introducer sheath if the venipuncture is unsuccessful. This could result in a sheared or severed sheath.
- Using nontoothed iris forceps, gently grasp the catheter about 1 cm from its distal end and insert it into the introducer sheath.
- With small, gentle strokes, a few millimeters at a time, advance the catheter to the premeasured length.
- Aspirate to visualize blood return, and flush with 0.5 to 1 mL of heparinized saline to clear the catheter.

  - Stabilize the catheter by applying gentle pressure to the vein proximal to the insertion site, then withdraw the introducer cannula. Carefully split and peel away the introducer sheath from the catheter.
  - Once the introducer sheath has been removed, verify catheter insertion length and adjust with forceps.
  - With a gauze pad, apply gentle pressure to insertion site to stop any bleeding.
  - Secure catheter at skin insertion site with sterile tape strips, and cover with sterile gauze until radiographic confirmation of position.

D. PICC Dressings (Figs. 31.5 and 31.6)

- Antimicrobial prep solutions should be removed from the skin with sterile water or saline and allowed to dry before placing dressing.
- To prevent migration of the catheter, secure it to the skin a few millimeters from the insertion site with a small piece of sterile tape.
- If the catheter has not been trimmed, loosely coil the excess length of catheter close to the insertion site and secure to the skin with more sterile tape. Ensure that there is no kinking or stretching of the catheter under the dressing.
- Some manufacturers caution against placing tape that contains a wire directly on the silicone catheter. If the catheter is trimmed to the appropriate length, it may not be necessary to place sterile tape on the catheter.
- Apply a semipermeable transparent dressing over the area surrounding the insertion site.
- Do not allow tapes or transparent dressing to extend around the extremity. The dressing will form a constricting tourniquet as the infant grows or if there is venous congestion.
- Place tape under the catheter hub and criss-cross it over the hub (chevron). Do not obscure visualization of the insertion site (Fig. 31.6).
- To prevent skin breakdown, a skin barrier can be placed under the hub (e.g., Duoderm [Convatec: Bristol-Myers Squibb, Princeton, NJ, USA] or soft gauze). Ensure that the hub is secured.

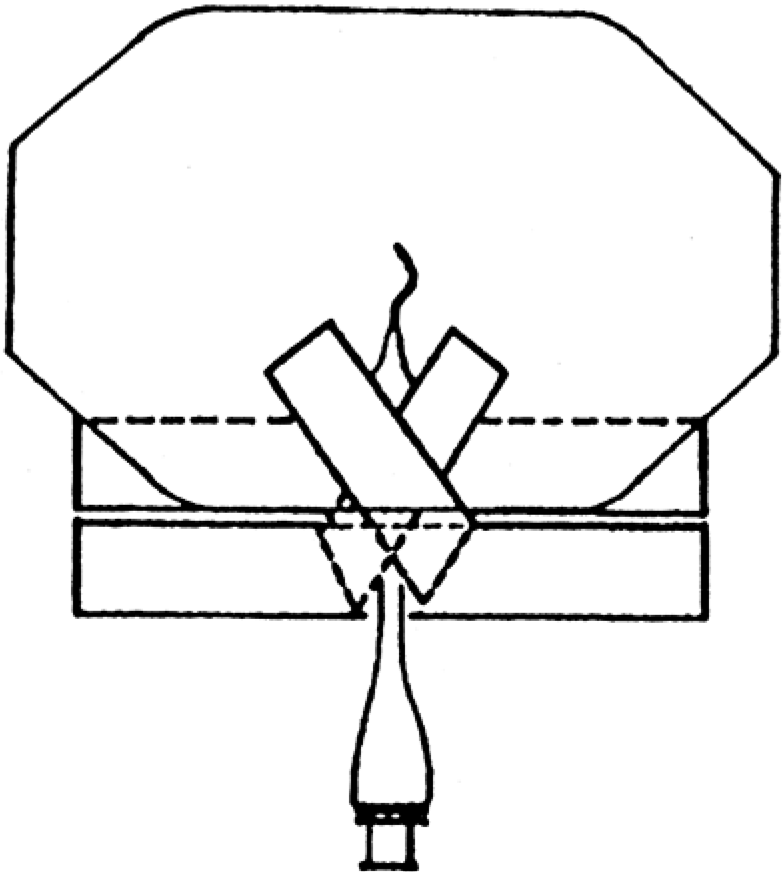

FIG. 31.6. Peripherally inserted central catheter dressing with trimmed catheter. No excess catheter is present externally. The silicone heart is anchored with a piece of tape, and a sterile transparent dressing is placed over the insertion site. With use of a â€œchevronâ€□ technique, another piece of tape is placed under the catheter extension, next to the silicone heart, and crossed over on top of the transparent dressing. (From Klein C. NeoPicc: The Neonatal and Pediatric Workshop Manual. San Antonio, TX: Klein Baker Medical, 1998, with permission.)

E. Dressing Changes

- Mild oozing of blood from the insertion site may occur for up to 24 hours. If oozing occurs, the initial dressing should be changed when it subsides. If oozing of blood is a problem, a small piece of thrombolytic foam can be applied over the insertion site and under the dressing for the first 24 hours after insertion.
- The catheter site dressing should be replaced when it becomes damp, soiled, or loose. Transparent dressings should be changed every 7 days except in those patients in whom the risk of dislodging the catheter outweighs the benefit of changing the dressing (22).
- Inspect catheter site carefully at each dressing change (Table 31.4).
- Catheter may be pulled back if it is too far in, prior to replacing dressing. Do not advance catheter, as the risk of contamination is high.
- Use sterile technique for dressing changes (mask, cap, and sterile gloves; sterile gown is optional).
- Prepare sterile field: Place drape under extremity. Utilizing the prep solution, prepare the skin at and around the insertion site, working outward in concentric circles. Allow the prep solution to dry. Repeat process with new gauze/prep solution. Drape prepared area, leaving insertion site exposed.
- Follow steps D1 through D8 to complete the PICC dressing change.

TABLE 31.4 Examination of the Catheter Site

Assessment	Comments
Catheter: Note external catheter length	Catheter length should be clearly documented. If external length has changed, get radiograph to assess where the catheter tip is located. If the catheter is pulled out, cover site with occlusive dressing and measure catheter length to assure that some of the catheter was not retained in the vessel.
Assess for kinks, tension, damage	Kinks and tension can damage catheter. It is recommended that damaged catheters be removed, but some manufacturers provide repair kits.
Insertion site/surrounding skin: Erythema, drainage, bleeding, edema, phlebitis, skin breakdown	Mild erythema and/or phlebitis is common after the catheter is inserted. If condition is severe and/or is persistent, consider removing catheter. Mild oozing of blood should not persist longer than 24 h. Edema may be due to venous stasis from lack of extremity movement, constrictive dressings, thrombus, damage to internal structures, localized infection, or infiltration of infusion into soft tissue. Avoid skin breakdown by utilizing skin barriers underneath hub, removing dressing adhesives with care, minimizing tape, and removing antiseptics from skin before applying dressing.
Drainage/leaking	Purulent drainage may be due an infectious process. Consider obtaining blood cultures and/or removing the catheter. Clear drainage may be indicative of infusion leakage. This may be due to catheter occlusion, infiltration, or damage to catheter.

F. PICC Care and Maintenance

- Evaluate appearance of the catheter and the tissue around the insertion site frequently.
- Change tubing according to unit policy. Utilize aseptic technique when changing tubing.
- To prevent contamination of the line, enter the PICC only when absolutely necessary. Maintain sterility at connection site when entering the line.
- Do not utilize the PICC for routine blood sampling.
- Prime volumes are usually less than 0.5 mL. Use a 5- to 10-mL syringe when needed to check catheter patency. Do not use force if resistance is encountered. A small-barreled syringe (such as a 1-mL syringe) may generate too much pressure, resulting in catheter rupture (21).
- Add 0.5 to 1 U of heparin/mL of intravenous fluids. The effectiveness of heparin in the prevention of PICC occlusion and catheter thrombosis is unclear at present (23).
- Administer a constant infusion of intravenous fluids at a rate of at least 1 mL/h. Follow the manufacturer's recommendations for maximum flow rates.
- Ensure that medications infused through the line are compatible with IV fluids or that the line is flushed, before and after medication administration.
- Packed red blood cell transfusions should be given through a PICC only in an emergency, as the small catheter size may cause occlusion or hemolysis when older blood is used (24). A peripheral intravenous cannula should be utilized for blood transfusions.
- Monitor quality indicators in order to identify and solve problems. Infection rates, catheter dwell times, patient outcomes, and rates of complications should be monitored (22).
- Remove catheter as soon as it is no longer medically necessary by slowly withdrawing it from insertion site. Clean insertion site with prep prior to withdrawing catheter. Hold pressure over site if bleeding is a problem. Remove prep from skin. Place a clean gauze dressing over site. Document length removed.

Placement of Central Venous Catheters by Surgical Cutdown

A. Types of Catheters

Silicone catheters are preferred because they are constructed of relatively inert materials, offer increased pliability, and are associated with lower rates of infection and thrombosis. These catheters are placed in a central vein, and the distal end is tunneled subcutaneously a short distance from the access site to an exit wound. The catheters usually have a single lumen with a Dacron cuff, which adheres to the subcutaneous tract, anchoring the catheter. Polyethylene catheters have a higher rate of infection and thrombolytic complications and are not recommended for long-term intravenous access.

B. Contraindications

In addition to the relative contraindications delineated earlier, the internal jugular vein should be avoided if the contralateral jugular vein has been catheterized previously, or if there is thrombosis of the jugular venous system on the opposite side.

C. Equipment

Sterile

- Skin prep: Per institutional policy (e.g., 10% povidoneâ€"iodine, or 0.5% chlorhexidine solution)
- Gown and gloves
- Cup with antiseptic solution
- Sterile transparent aperture drape; four sterile towels to ensure a sterile operative field
- Four 4-4-in gauze squares
- Local anesthetic: 0.5% lidocaine HCl in labeled 3-mL syringe with 25-gauge venipuncture needle

  Consider sedation and pain medication in addition to local anesthesia. Patients who are intubated may be given a sedative and muscle relaxant in addition to local anesthesia. When patients are taken to the operating room, general anesthesia is preferred.

- Catheter of choice
- Heparinized 0.25 N saline flush solution (1 U/mL) in 3-mL syringe
- 4-0 Polyglactin suture (Vicryl; Ethicon, Somerville, NJ, USA) and 5-0 nylon suture (black monofilament nylon) on cutting needles (see Appendix B)
- T connector connected with a sterile 3-mL syringe filled with heparinized saline
- No. 11 scalpel blade and holder
- Two small tissue retractors or self-retaining retractor
- Tissue forceps
- Fine vascular forceps
- Two small, curved mosquito hemostats
- Dissecting scissors
- 4-0 Vicryl suture on small, curved needle; 6-0 polypropylene on a tapered needle. This is used for a purse-string stitch as an alternative to ligation of the vessels.
- Needle holder
- Suture scissors
- Appropriate materials for occlusive dressing of choice

Nonsterile

- Cap and mask
- Roll of 4- Ã— 4-in gauze
- Tape measure
- Adhesive tape

D. Techniques

In the neonate, the cervical veins are preferable to the lower-extremity veins. The cervical veins are easily accessible and are a proportionately larger size. When the lower extremities are used, the greater saphenous vein is often selected in pediatric patients because of its large size and consistent anatomy. It is not established whether femoral or jugular sites have fewer complications in neonates (25, 26).

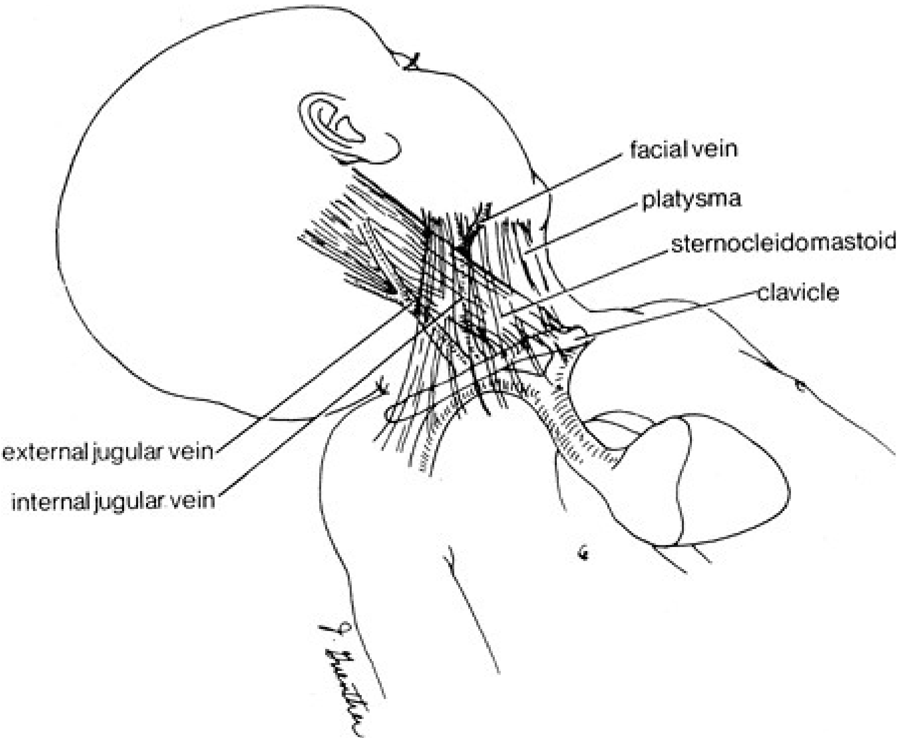

FIG. 31.7. The jugular veins in relation to major anatomic landmarks.

- Catheter placement via jugular veins
    - Immobilize infant in position similar to that for percutaneous insertion of subclavian venous catheter.
    - If right side is to be catheterized, turn head to left and extend neck. Care must be taken not to extend the head too much, as this may result in occlusion of the neonatal vein.
    - Estimate length of catheter to be inserted by measuring from a point midway between the nipple and the midpoint of the clavicle to a point over the sternocleidomastoid muscle at the junction of the middle and lower third of the neck (Fig. 31.7).
    - Put on cap and mask.
    - Scrub as for major procedure and put on gown and gloves.
    - Prepare neck and scalp area or right chest wall with antiseptic solution such as iodophor and drape out the sterile field.
    - Make small, transverse incision (1 to 2 cm) through skin and platysma muscle low in the neck for the external jugular and higher up for the facial vein.
    - Free external jugular or facial vein by blunt dissection with curved mosquito hemostat. If internal jugular vein is used, sternocleidomastoid muscle must be split to locate vein.

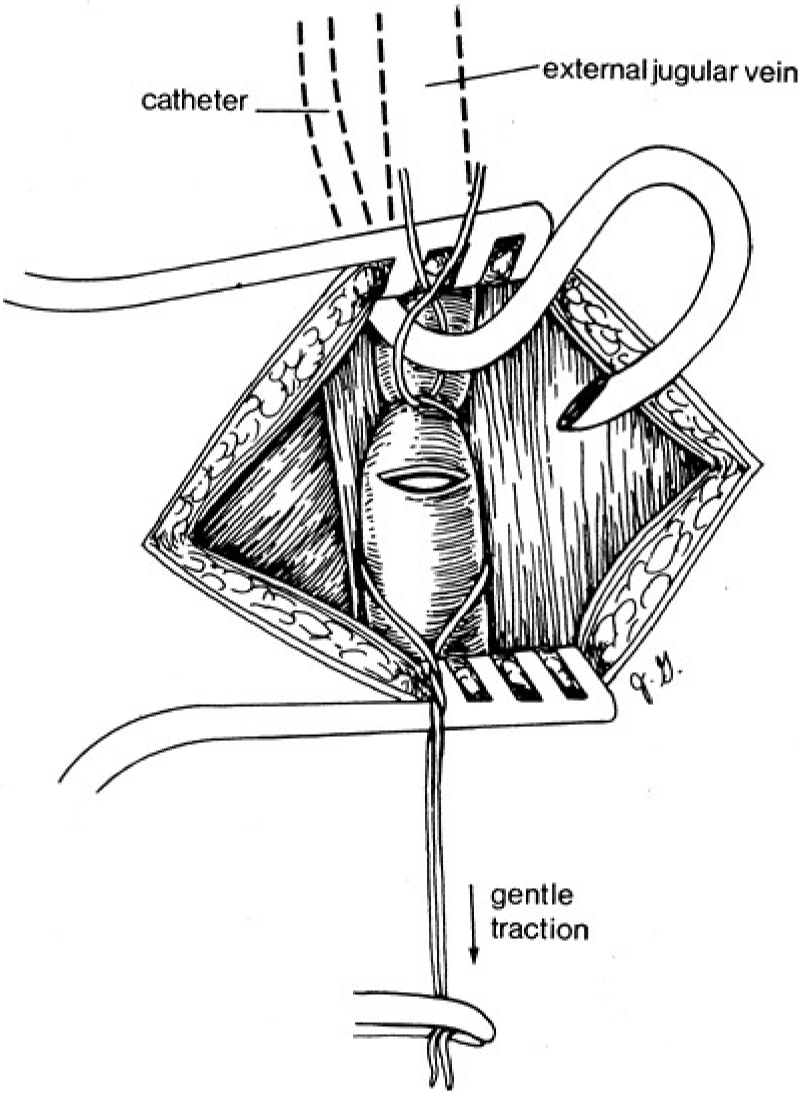
catheter
external jugular vein
gentle traction
J. M.

FIG. 31.8. Catheterization of the external jugular vein; venotomy has been performed prior to inserting the catheter.

- Pass curved mosquito hemostat behind the vein, and place proximal and distal ligatures of 4-0 absorbable suture loosely around vein (Fig. 31.8). Be careful not to twist the vessels as the suture is advanced.

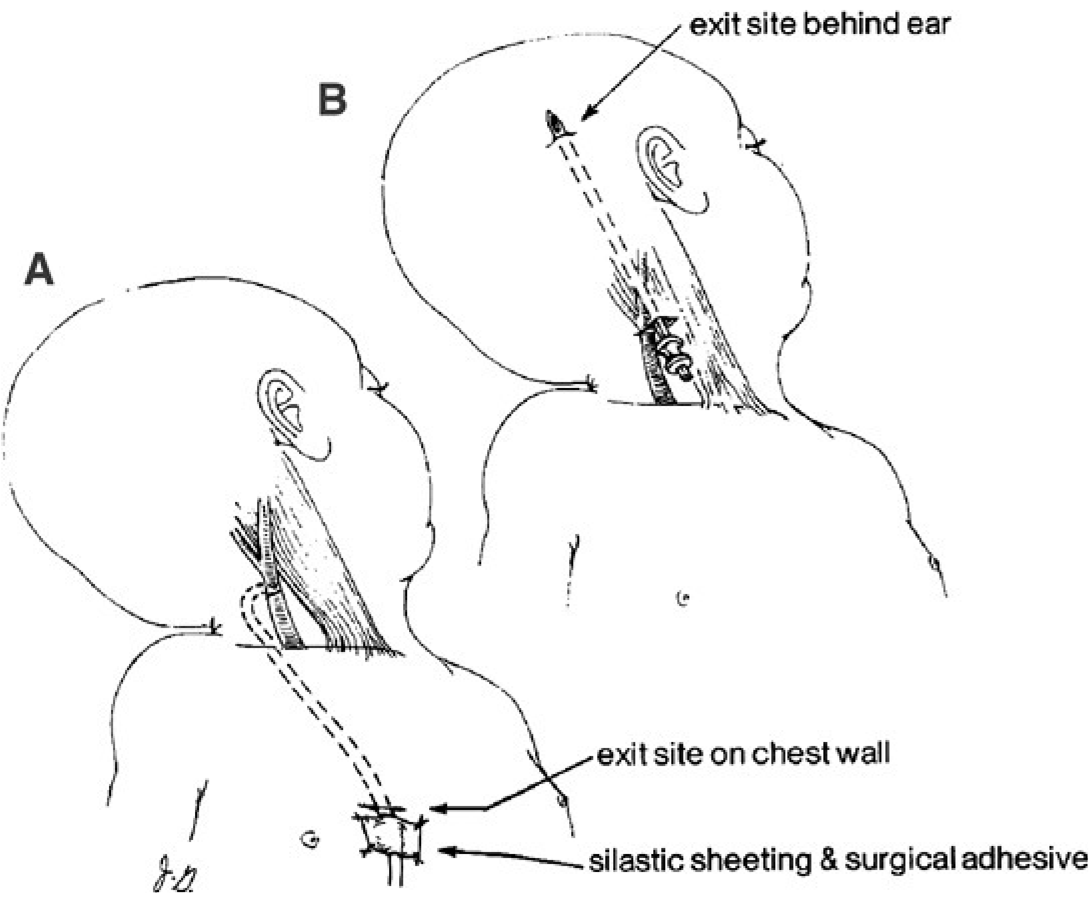

FIG. 31.9. Formation of a subcutaneous tunnel with a Vim-Silverman needle. A: Tunnel on the anterior chest wall. B: Alternative route under the scalp.

- Using a blunt tunneler, create a subcutaneous tract from neck to exit on the chest wall medial to the right nipple. In a baby girl, make sure that the tunnel is far from the breast bud (Figs. 31.9 and 31.10).
- Thread the end of the catheter through the opening in the tunneler, and guide the catheter gently through the subcutaneous tract.
- Fill the catheter system with heparinized flush solution.
- Cut the catheter length to the premeasured distance between the neck incision and a point midway between the center of the nipple line and the suprasternal notch.
- Perform transverse venotomy (Fig. 31.8).

  For external jugular or facial vein (27)

    - Tie cephalad venous ligature, and exert traction on both ligatures in opposite directions with aid of appropriately prepared assistant.
    - Make short, transverse incision in anterior wall of vein, and enlarge gently by inserting and spreading tips of fine vascular forceps.

  For internal jugular vein

    - To avoid ligation of the vessel, use purse-string suture of 6-0 polypropylene, placed in vessel wall around point of catheter entrance.
    - Make incision in vessel as for external jugular vein.
- Bevel intravascular end of catheter (optional).

  - Grasp catheter gently with blunt nontoothed tissue forceps, introduce catheter tip, and insert into the vein.
  - Leave loop of catheter in neck wound to dampen effect of head movement (Fig. 31.11).
  - Close wound with subcuticular 5-0 absorbable suture, taking care not to penetrate the catheter.
  - Secure the catheter to the skin with at least one nylon suture to hold it until the cuff has created enough tissue ingrowth.
  - Use selected method for fixation and dressing.

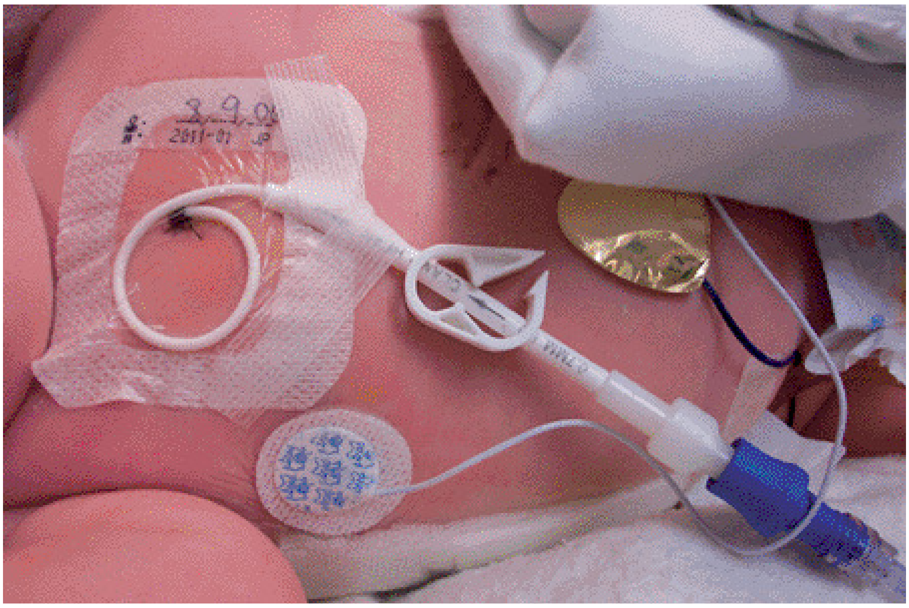

FIG. 31.10. Broviac catheter with transparent dressing.

- Proximal saphenous vein cutdown
  - Scrub and prepare as for major procedure.
  - Prepare as for cutdown on jugular vein.
    - Choose right or left groin area for insertion.
    - Prepare groin and abdomen on same side.
  - Make incision 1 cm long: 1 cm caudad and 1 cm lateral to pubic tubercle (Fig. 31.12).
  - Spread incision into subcutaneous tissues, using curved mosquito hemostat.
    - Incise superficial fascia.
    - Identify saphenous vein lying medial and inferior to its junction with femoral vein at foramen ovale (Fig. 31.12).
  - Move 0.5 to 1 cm distally before
    - Passing curved mosquito hemostat behind vein. This avoids inadvertent damage to femoral vein.
    - Placing two 4-0 absorbable suture ligatures loosely around vein
  - Create tunnel, using small hemostat or tunneling instrument, in subcutaneous plane laterally onto abdomen, just above or lateral to umbilicus or on lateral thigh.
  - Flush catheter with heparinized saline and replace cap.

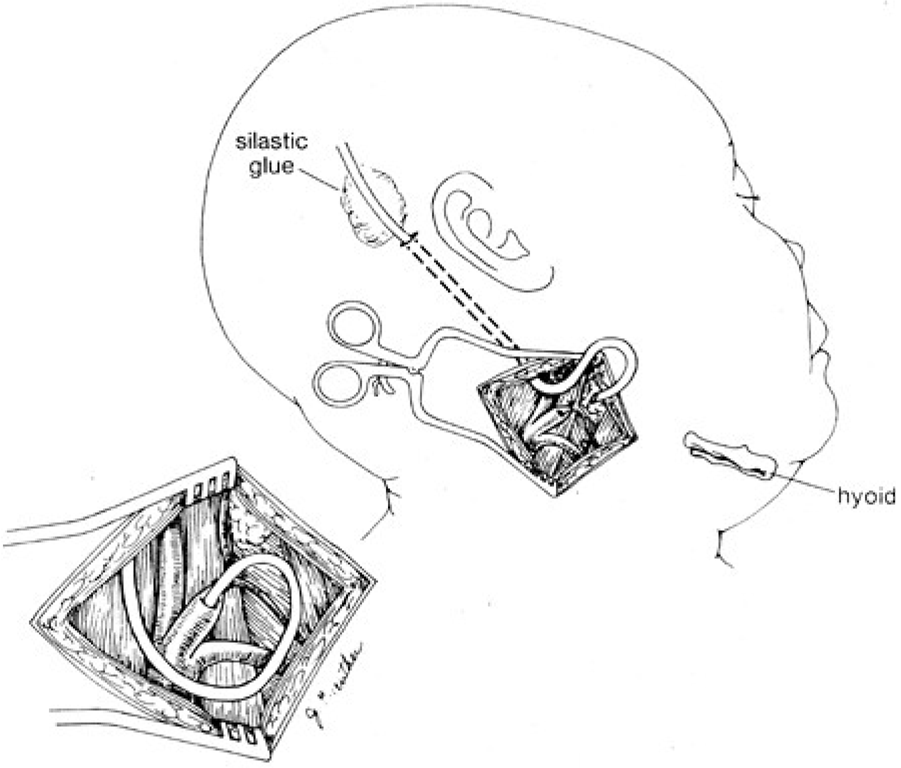

FIG. 31.11. Insertion of a catheter into the common facial vein. Incision is below the angle of the mandible at the level of the hyoid bone. The facial vein is ligated at the junction of the anterior and posterior tributaries. Inset: The catheter is looped in the neck wound to dampen the effect of head movement. Alternatively, a subcutaneous tunnel may be made with a catheter exit site on the anterior chest wall. (Reproduced from Zumbro GL Jr, Mullin MJ, Nelson TG. Catheter placement in infants needing total parenteral nutrition utilizing common facial vein. Arch Surg. 1971;102:71, with permission of American Medical Association.)

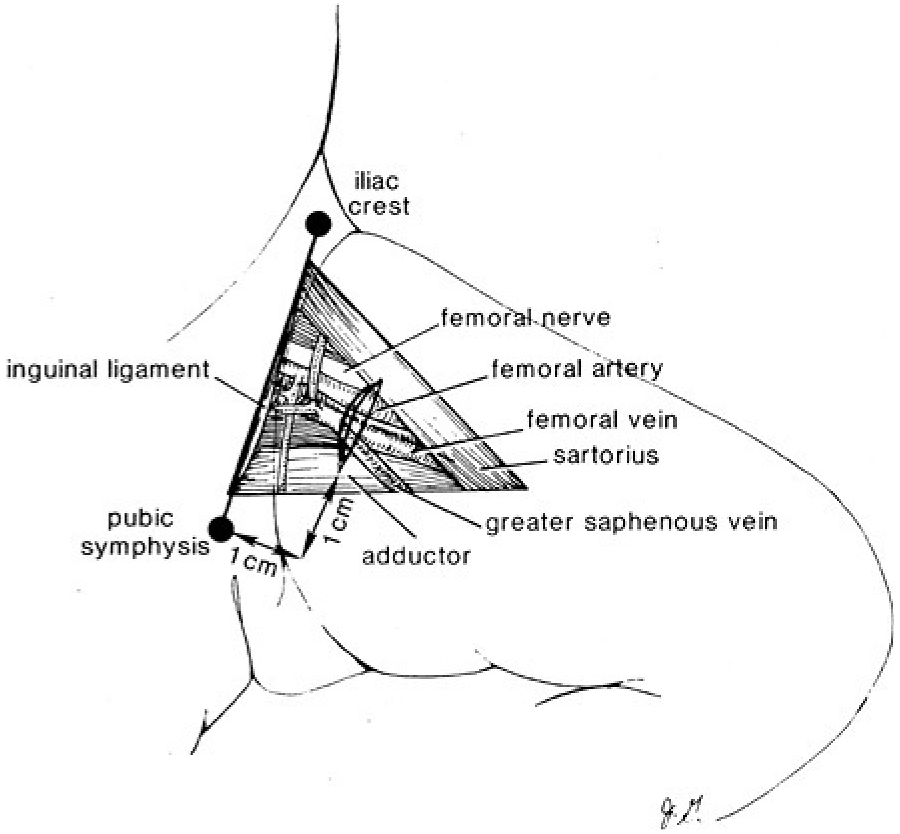

FIG. 31.12. Anatomic view of the site of incision for proximal saphenous vein cutdown with underlying femoral triangle.

- Pull catheter through tunnel into groin wound so that Dacron cuff is just within the skin incision.

  Estimate length of catheter to be inserted so that tip will be in inferior vena cava at junction with right atrium.

- Cut catheter to appropriate length, and bevel intravascular end (optional).
- Dissect saphenous vein to junction with common femoral vein.
- Visualizing the junction prevents inadvertent direction of catheter into lower extremity.
- Apply traction to vein, using caudad suture. Lateral tension may also be applied by a scrubbed assistant, using fine nontoothed vascular forceps.
- Make transverse venotomy.
- Dilate vein, if necessary, with blunt dilatator.
- Moisten catheter with saline to ease passage into vein.
- Maintain back-traction on caudad suture to control bleeding.
- Visualize catheter entering common femoral vein to ensure cephalad direction of catheter.
- Obtain radiograph to confirm position in inferior vena cava, once estimated length is inserted (radiographic contrast material may be required).
- Ligate vessel with caudad suture, and tie down cephalad suture without occluding catheter.
- Check for easy backflow of blood in catheter.
- Flush catheter with 2.5 to 3 mL of heparinized saline. If catheter is capped, while infant is transferred from operating room to intensive care unit, clamp catheter while plunger of heparin syringe is moving forward to ensure positive pressure in line to prevent backflow and clotting of blood.

  - Close groin wound with subcuticular 5-0 absorbable suture, taking care not to penetrate catheter with needle.
  - Secure the catheter to the skin with at least one nylon suture to hold it until the cuff has created enough tissue ingrowth.
  - Cover with dressing of choice.

E. Sterile Dressing for Surgically Placed Central Venous Lines

Routine changing of central venous catheter dressings depends on the type of dressing. Transparent dressings should be changed at least every 7 days, and gauze dressings every 2 days. All dressings should be changed when damp, loose, or soiled (22).

Equipment

Strict sterile technique is used for all central line dressings.

- Antiseptic skin prep solution: Per institutional policy (e.g., 10% povidoneâ€“iodine or 0.5% chlorhexidine solution)
- Sterile gloves, mask, cap, and sterile gown (optional)
- Scissors (optional)
- Cotton-tipped applicator
- 4- Ã— 4-in sterile gauze square
- Dressing of choice
  - Semipermeable transparent dressing
  - Sterile 2- Ã— 2-in gauze squares or presplit 2- Ã— 2-cm gauze dressing
- Normal saline or sterile water
- Adhesive tape (if sterile tape not available, use fresh unused roll)

Precautions

- Procedure should be undertaken by trained personnel.
- Ensure that all personnel wear masks if within 6-ft radius of sterile area.
- Use strict aseptic technique.
- Remove dressing with care, to avoid cutting or dislodging catheter.
- If it is necessary to clamp the catheter, close the clamp on the catheter according to the manufacturer's directions. If the catheter does not have a clamp, use a rubber-shod clamp. Never place a clamp directly on the catheter.
- Never advance a dislodged catheter into the patient.
- Do not place adhesive tape on silicone tubing because this may occlude or damage the catheter.
- Do not routinely apply prophylactic topical antimicrobial or antiseptic ointment at the insertion site because of the potential for promoting fungal infections and antimicrobial resistance (22).

Technique

When a subcutaneous tunnel is used, occlusive dressing should be applied to both the cutdown site and the catheter exit site.

- Restrain patient appropriately, utilizing nonpharmacologic comfort measures.
- Put on head cover and mask.
- Scrub as for major procedure.
- Put on gown and gloves.
- Prepare sterile work area, using â€œno-touchâ€□ technique.
- Remove old dressing and discard.
- Inspect catheter site carefully (Table 31.4).
- Culture site if there is drainage or it appears inflamed.

- If area around catheter is contaminated with dried blood or drainage, clean with diluted hydrogen peroxide/sterile water solution (1:1).
- Remove gloves. Don sterile gloves.
- Cleanse area with antiseptic solution, starting at catheter site and working outward in circular motion for 2 to 4 cm. Repeat twice. Allow area to dry.
- Remove antiseptic with sterile water or saline gauze and allow to dry.

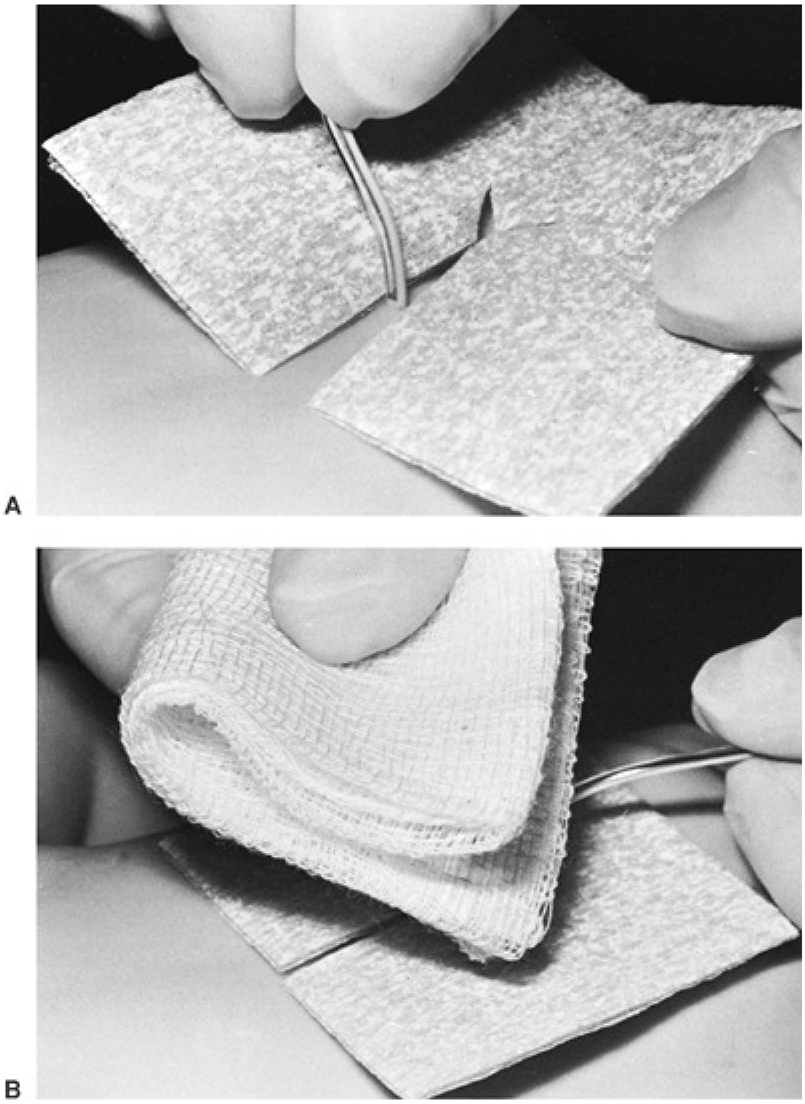

FIG. 31.13. Occlusive dressing for a central venous line using presplit gauze. A: Placing split gauze over the skin entry site. B: Covering split gauze and the catheter with sterile gauze. Entire dressing is then covered with adhesive tape or clear dressing.

- Apply dressing of choice.
    - Clear, adhesive, hypoallergenic, transparent dressing allows for continuous inspection of catheter insertion site (Fig 31.10).
        - If necessary, cut dressing to desired size.
        - Anchor dressing to skin above catheter skin entry site, so that the point of skin entry is at the center of the dressing.
        - Remove remainder of adhesive backing while applying dressing smoothly over site.
    - Standard occlusive gauze dressing
        - Cut gauze halfway across, or use presplit gauze. Place around catheter as shown in Fig. 31.13.
        - Cover remainder of external catheter length (not hub) with sterile gauze.

        - If sterile tape is not available, discard outer layer of tape on roll.
        - Cover gauze with tape.
        - Label dressing with initials and date.
        - Secure intravenous tubing with tape to prevent tension on the center (a stress loop can decrease tension on the catheter).

F. Care of the Catheter When Not in Use for Continuous Infusion

Indications

To maintain patency and prevent clotting of the catheter when the line is used intermittently. Only large-bore catheters (2.5 Fr or larger) may be kept patent by this technique. PICC lines that are 2 Fr or smaller tend to clot easily if continuous infusions are interrupted.
Equipment

- 3 mL of heparinâ€"saline solution (10 U/mL) in a 10-mL syringe (follow manufacturer's guidelines for syringe sizes)
- Alcohol wipes
- Catheter clamps (must have no teeth or be padded), or use clamp provided on catheter (Fig. 31.10)
- Clean gloves
- Intravenous injection cap (needleless is recommended)

Technique

- Converting to a heparin lock
    - Wash hands thoroughly.
    - Don clean gloves.
    - Prepare sterile work area.
    - Using aseptic technique, open sterile injection cap package and prefill injection cap with heparinized saline.
    - Clean the outside of the hubâ€"intravenous tubing connection with an antiseptic such as alcohol wipes. Work outward in both directions. Allow to dry.
    - Clamp catheter with padded hemostat, or close catheter clamp.
    - Holding hub with alcohol swab, disconnect catheter hub from intravenous tubing.
    - Connect preflushed injection cap into hub of catheter (gently flushing during connecting can prevent air from entering catheter).
    - Release clamp and flush line with 1 to 3 mL of heparinized saline (depending on size of catheter).
    - Reclamp catheter while plunger of heparin syringe is depressed to prevent blood from backing into catheter (positive pressure).
    - Secure catheter and tape to chest or abdomen.
    - Flush catheter with heparinized solution every 6 to 12 hours (per institution policy).
- Flushing catheters

    Equipment is same as for heparin lock.

    - Wash hands thoroughly.
    - Put on gloves and prepare sterile work area.
    - Prepare intravenous injection cap with antiseptic solution. Allow to dry.
    - If injection cap is part of a needleless system (recommended), connect flush syringe to cap. If the cap is not a needleless device, insert needle into intravenous catheter plug. Always use a 1-in needle. A longer needle can puncture the catheter.

  - Unclamp catheter and slowly inject 1 to 2 mL of heparin solution (depending on catheter size). Reclamp catheter while injecting solution to prevent blood from flowing back into catheter. Positive-pressure injection caps are available to prevent backflow.
  - Changing intravenous catheter injection cap: Most manufacturers recommend changing injection caps every 3 to 7 days, after blood product administration, or when they appear damaged (see specific manufacturer's instructions).

Catheter Removal

A. Indications

- Patient's condition no longer necessitates use.
- Occluded catheter
- Local infection/phlebitis
- Sepsis and/or positive blood cultures obtained through the catheter (catheter colonization). There are rare clinical circumstances when a catheter is left in place despite sepsis and antibiotic or antifungal therapy is administered through it in an attempt to clear the infection, but this may be associated with an increased risk of morbidity and mortality (28, 29).

B. Technique

Surgically implanted central venous catheters should be removed by a physician or other person specifically trained to remove cuffed and/or tunneled catheters.

- Remove dressing.
- Pull catheter from vessel slowly over 2 to 3 minutes.

  Avoid excessive traction if catheter is tethered, because the catheter may snap (see Complications).

- Apply continuous pressure to the catheter insertion site for 5 to 10 minutes, until no bleeding is noted.
- Inspect catheter (without contaminating tip) to ensure that entire length has been removed.
- The cuff on the tunneled catheter should be dissected out under local anesthesia with IV sedation. If cuffs are retained, they may rarely cause more than a persistent small subcutaneous lump, although they can occasionally extrude through the skin.
- If desired, antibiotic ointment may be placed over site.
- Dress with small, self-adhesive bandage or gauze pad and inspect daily until healing occurs.

Complications of Central Venous Lines

- Damage to other vessels and organs during insertion
  - Possible during both percutaneous and surgical placement of central venous catheters
  - Complications include bleeding, pneumothorax, pneumomediastinum, hemothorax, arterial puncture, and brachial plexus injury (20, 30, 31).
- Phlebitis
  - Mechanical phlebitis may occur in the first 24 hours after line placement as a normal response of the body to the irritation of the catheter in the vein.
  - Management of mild phlebitis (mild erythema and/or edema): Apply moist, warm compress, and elevate extremity.
  - Remove the catheter if symptoms do not improve, if phlebitis is severe (streak formation, palpable venous cord, and/or purulent drainage), or if there are signs of a catheter-related infection.

- Catheter migration/malposition (2, 8, 9, 10, 11, 12, 13, 16) (Fig 31.14)
    - Can occur during insertion or from spontaneous migration at any point during the catheter dwell time. During insertion, the catheter can enter a side vein or reverse direction, causing it to loop or curl backward.
    - Sites of misplacement include the cardiac chambers, internal jugular vein, contralateral subclavian vein, ascending lumbar vein, and others, with consequences such as pericardial effusion or pleural effusion, cardiac arrhythmias, tissue extravasation/infiltration, and thrombosis.
    - The decision to remove the catheter or attempt to correct the position is based on the location of the tip. Although PICCs are intended to be placed in central veins, occasionally, the tip is in a noncentral location (e.g., in the subclavian vein). These noncentral PICCs may be used temporarily, provided the fluids administered through them are isotonic, but the care of the catheters must be as stringent as for centrally placed catheters (32).
    - The catheter should be pulled back a few centimeters if the tip is in the heart, as serious consequences such as cardiac arrhythmia, perforation, or pericardial effusion can occur.
    - Spontaneous correction of malpositioned lines has been demonstrated in some cases (33). If the tip of the catheter is looped into the internal jugular or in the contralateral brachiocephalic vein, the catheter may be used temporarily (using isotonic fluids that are suitable for peripheral venous cannulae) and re-evaluated radiologically in 24 hours. If the catheter has not moved spontaneously into the desired location, it should be removed.
- Infection (most common complication)
    - Catheter-related sepsis (CRS) rates range from 0% to 29% of lines placed and from 2 to 49 per 1,000 catheter days, with the smallest and most immature infants being at greatest risk (2, 34, 32, 36).
    - Strict protocols for central line care and a methodology of surveillance with a data feedback mechanism are recommended to decrease the rate of infection, which can vary significantly among neonatal intensive care units (4, 22, 34, 36).
    - Management of catheter-related sepsis: Remove central venous line if possible. Prompt removal of the line is recommended for Staphylococcus aureus, gram-negative, or Candida sepsis. Treatment with appropriate antibiotics without removal of the line may be attempted in infants with coagulase-negative Staphylococcus sepsis, but repeated positive cultures mandate removal of the line (28, 29).
- Catheter dysfunction
    - Obstruction of the catheter is characterized by increased pump pressures, or inability to infuse fluids or withdraw blood.
    - Dysfunction may be due to malposition, fibrin thrombosis, precipitates caused by minerals or drugs, or lipid deposits (36, 37).
    - Management
        - Check catheter position on chest radiograph.
        - If malposition is ruled out, review history of fluids and drugs administered through the catheter to determine probable cause of occlusion.
        - Remove the catheter if it is no longer medically critical.
        - Attempt clot dissolution only if maintenance of catheter is essential.
        - Equipment required: Face mask, sterile gloves and drape, prep solution, sterile three-way stopcock, a 10-mL syringe, and a 3-mL syringe filled with 0.2 to 0.5 mL of agent for clot dissolution.
        - Agents for clot dissolution (37)
            - Hydrochloric acid, 0.1 N, for calcium salt precipitates or drugs with pH < 7

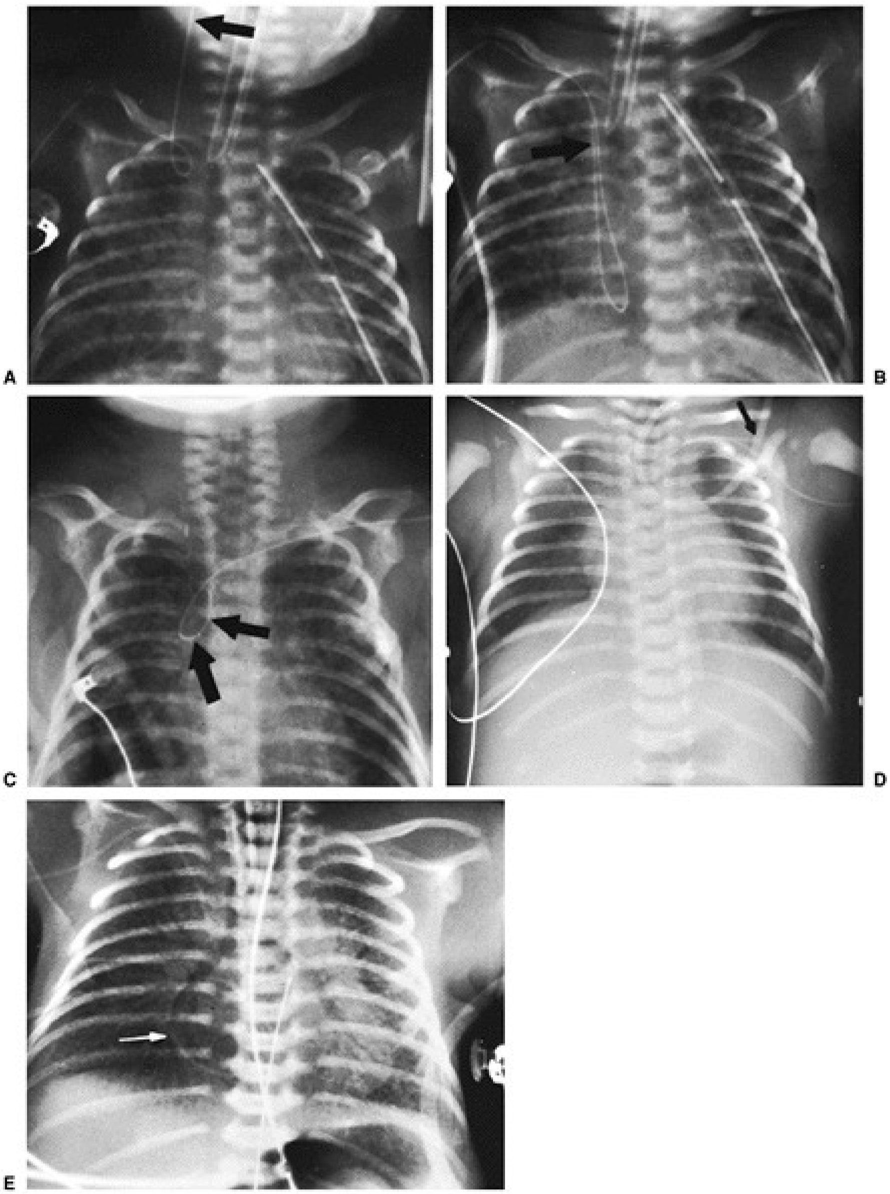

FIG. 31.14. Various venous malpositions of subclavian venous catheters. A: Jugular. B: Looped in the right atrium with the tip in the superior vena cava. C: Looped in the superior vena cava. D: Looped in the innominate vein with the tip overlying the left scapula. E: Knotted in the left atrium.

  - Sodium bicarbonate, 8.4%, 1 mEq/mL, for medications with pH > 7
  - Ethanol, 70% concentration, for lipid deposits
  - Recombinant tissue plasminogen activator, 0.5 to 1 mg/mL, for fibrin or blood clot (37, 38, 39)
  - Recombinant urokinase, 2,000 to 5,000 IU/mL, for fibrin or blood clot (40)
  -
- Technique
  - Use strict aseptic technique.
  - Remove IV tubing and cap to maintain sterility. After cleaning with prep, attach a three-way stopcock to catheter hub.

        - Attach an empty 10-mL syringe to the side port of the three-way stopcock and a prefilled 3-mL syringe to the other port. Avoid use of 1-mL tuberculin syringe.
        - Turn the stopcock off toward the prefilled syringe and open toward the empty syringe.
        - Aspirate on the empty syringe, creating negative pressure in the occluded catheter.
        - While maintaining the negative pressure, turn the stopcock off to the empty syringe and open to the prefilled syringe. The negative pressure in the catheter will automatically cause the medication in the prefilled syringe to flow into the catheter.
        - Allow the medication to dwell in the catheter for 20 minutes to 1 hour.
        - Aspirate after the dwell time to check for blood return, discard the aspirate, and flush the catheter with sterile normal saline. Resume catheter use.
        - If the procedure is unsuccessful, it may be repeated once, or a different declotting agent may be tried.
        - Do not use hydrochloric acid immediately before or after using sodium bicarbonate.
        - Continuous infusions of low-dose recombinant tissue plasminogen activator or urokinase may be attempted if bolus doses do not clear the occlusion. Risk of hemorrhagic complications should be evaluated (41, 42).

- Thrombosis, thromboembolism
    - About 90% of venous thromboembolic events in neonates are associated with central venous catheters (43). They include:
        - Deep venous thrombosis
        - Superior vena cava syndrome
        - Intracardiac thrombus
        - Pulmonary embolism
        - Renal vein thrombosis
    - The complications of venous thrombosis include loss of venous access, potential danger of injury to affected organ or limb, thrombus propagation, embolization to other areas, and infection.
    - Management of thromboembolism in neonates is controversial. The severity of thrombosis and the potential risk to organs or limbs dictate the degree of intervention required, including the use of thrombolytic/anticoagulant therapy or surgical intervention (44).
- Extravascular collection of fluid
    - Pericardial effusion with or without cardiac tamponade (Fig. 37.3) (2, 8, 9, 10, 11, 12, 13). This serious complication presents as sudden cardiac collapse or unexplained cardiorespiratory instability. The cardiothoracic ratio is increased, and pulsus paradoxus may be noted (Fig. 37.1). Immediate pericardiocentesis may be life-saving (Chapter 37).
    - Pleural effusion
    - Mediastinal extravasation
    - Hemothorax
    - Chylothorax
    - Ascites
- Catheter breakage
    - Catheters may be severed by the introducer needle during insertion of a PICC, snap because of excessive tension on the external portion of the catheter, or rupture because of excessive pressure. Other common causes include external clamps, kinking of the catheter, constricting sutures, and poorly secured catheters. The intravascular portion of the broken catheter is at risk for embolization (45).

  - In the event of catheter breakage, immediately grasp and secure the extravascular portion of the broken catheter to prevent migration.
  - If the catheter is not visible outside the baby, apply pressure over the venous tract above the insertion site to prevent the catheter from advancing. Immobilize the infant, and obtain a radiograph immediately to localize the catheter.
  - Surgical and/or cardiothoracic intervention may be required if the catheter is not visible externally.
  - Damaged or broken catheters must be removed and replaced. Repaired catheters and catheter replacement over a guidewire place the patient at risk for infection or embolization. If no other options exist owing to limited venous access, the catheter can sometimes be repaired, utilizing meticulous aseptic technique. Repaired PICCs should be considered temporary, and a new catheter should be placed as soon as possible. Some manufacturers offer repair kits and instructions. A butterfly or blunt needle may be used in an emergency (46) (Fig. 31.15).
- Tethered catheter
  - Difficulty in removing catheter may be due to the formation of a fibrin sheath or secondary to sepsis.
  - Management
    - Place warm compresses on skin along the vein.
    - Use gradual, gentle traction on the catheter.
    - Thrombolytic therapy (47)
    - Surgical removal through a peripheral incision

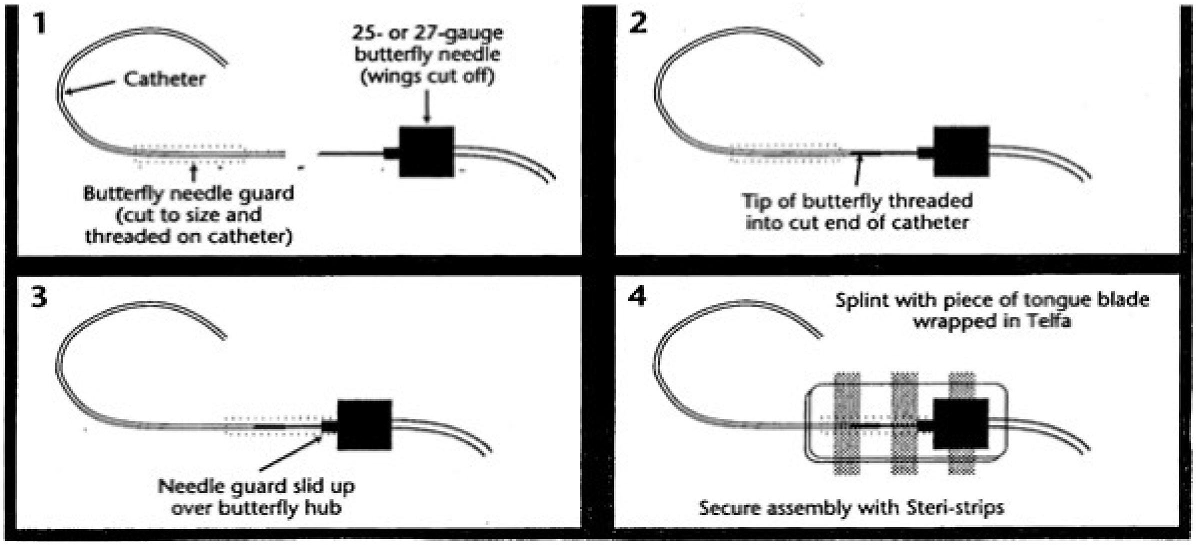
1
Catheter
25- or 27-gauge butterfly needle (wings cut off)
Butterfly needle guard (cut to size and threaded on catheter)
2
Tip of butterfly threaded into cut end of catheter
3
Needle guard slid up over butterfly hub
4
Splint with piece of tongue blade wrapped in Telfa
Secure assembly with Steri-strips

FIG. 31.15. Emergency catheter repair using butterfly needle (46). (From Neonatal Network, Santa Rosa, CA, USA, with permission.)

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32-Extracorporeal Membrane Oxygenation Cannulation and Decannulation

Khodayar Rais Bahrami
Gary E. Hartman
Billie Lou Short

Extracorporeal membrane oxygenation (ECMO) is defined as the use of a modified heartâ€“lung machine combined with a membrane oxygenator to provide cardiopulmonary support for patients with reversible pulmonary and/or cardiac insufficiency in whom maximal conventional therapies have failed (1,2,3). After decades of laboratory and clinical research, ECMO is now well accepted as a standard of treatment for neonatal respiratory failure refractory to conventional techniques of pulmonary support (4,5,6,7). Most causes of neonatal respiratory failure are self-limited, and ECMO allows time for the lung to recover from the underlying disease process and for reversal of pulmonary hypertension, which frequently accompanies respiratory failure in the newborn.

Venoarterial Extracorporeal Membrane Oxygenationâ€”Cannulation

A. Indications

Placement of carotid arterial and internal jugular venous catheters for use in venoarterial ECMO. Venoarterial ECMO should be used in patients with significant cardiovascular instability.

B. Relative Contraindications for Extracorporeal Membrane Oxygenation in the Neonatal Period (5,7)

- Gestational age <34 weeks
- Birthweight <2,000 g
- Uncontrolled coagulopathy or bleeding disorders
- Congenital heart disease without lung disease. Exception: Postoperative cardiac patients, a topic that will not be covered in this chapter
- Irreversible lung pathology
- Intracranial hemorrhage >Grade I to II
- Major lethal congenital anomaly
- Duration of maximum ventilatory support, >10 to 14 days
- Significant positive response to ventilator management and/or inhaled nitric oxide (iNO)

C. Precautions

- Ensure that the patient is paralyzed before placing the venous catheter, to prevent air embolus.
- Recognize that:
    - Internal jugular lines placed for intravenous access prior to ECMO may cause clot formation, resulting in the need for thrombectomy before placement of the venous ECMO catheter.
    - Excessive manipulation of the internal jugular vein may cause spasm and inability to place a catheter of appropriate gauge.
    - A lacerated vessel may result in the need for a sternotomy for vessel retrieval.

      Appropriate instruments should be on the bedside tray or cart. A backup unit of blood should be available in the blood bank.

    - Blood loss sufficient to produce hypotension can occur during a difficult cannulation.

      Emergency blood should be available at the bedside (10 to 20 mL/kg).

  - The vagus nerve is located next to the neck vessels and may be injured or manipulated during isolation of the vessels. Manipulation can cause bradycardia or other arrhythmias.
  - Vital signs and pulse oximetry values must be monitored at all times because clinical observation of the infant is prevented by the surgical drapes.
  - If the patient has been hand bagâ€“ventilated for stabilization, do not place the Ambu bag on the bedside when surgical drapes are placed. The bag may entrap oxygen, which can result in a fire when electrocautery is used.

D. Personnel, Equipment, and Medications (8)

Personnel

- Surgical team
  - A senior surgeon (pediatric, cardiovascular, or thoracic) with assistant
  - A surgical scrub nurse and a circulating nurse
- Medical team
  - A physician trained in management of ECMO patients and cannulation techniques, who will administer anesthetic agents and manage the infant medically during the procedure
  - A bedside intensive care (neonatal or pediatric intensive care unit) nurse, who will monitor vital signs, record events, and draw up medications as needed by the ECMO physician
  - A respiratory therapist, who will change ventilator settings as necessary
- Circuit specialists
  - A cardiovascular perfusionist, nurse, or respiratory therapist specially trained in this procedure, who will prime the pump
  - A bedside ECMO specialist (nurse, respiratory therapist, or cardiovascular perfusionist with special training in ECMO management), who will manage the ECMO system after the patient is on ECMO

Equipment (Fig. 32.1)
Sterile

- Arterial and venous catheters (9)
  - Arterial
    - The size of the arterial catheter determines the resistance of the ECMO circuit, because it is the part of the ECMO circuit with the smallest internal diameter and thus the highest resistance.
    - This catheter should be as short as possible, with a thin wall and a large internal diameter (resistance is related directly to the length of the catheter and inversely to the diameter). An example of a suitable catheter is the Bio-Medicus Extracorporeal Circulation Cannula, 8 to 10 French (Fr) (Bio-Medicus, Minneapolis, MN, USA).
  - Venous
    - The venous catheter should have as large an internal diameter as possible to allow maximal blood flow (the patient's oxygenation is related directly to the rate of blood flow).
    - Should be thin walled with a large internal diameter. An example of a suitable catheter is the Bio-Medicus Extracorporeal Circulation Cannula, 8 to 14 Fr. (Bio-Medicus, Minneapolis, MN, USA).

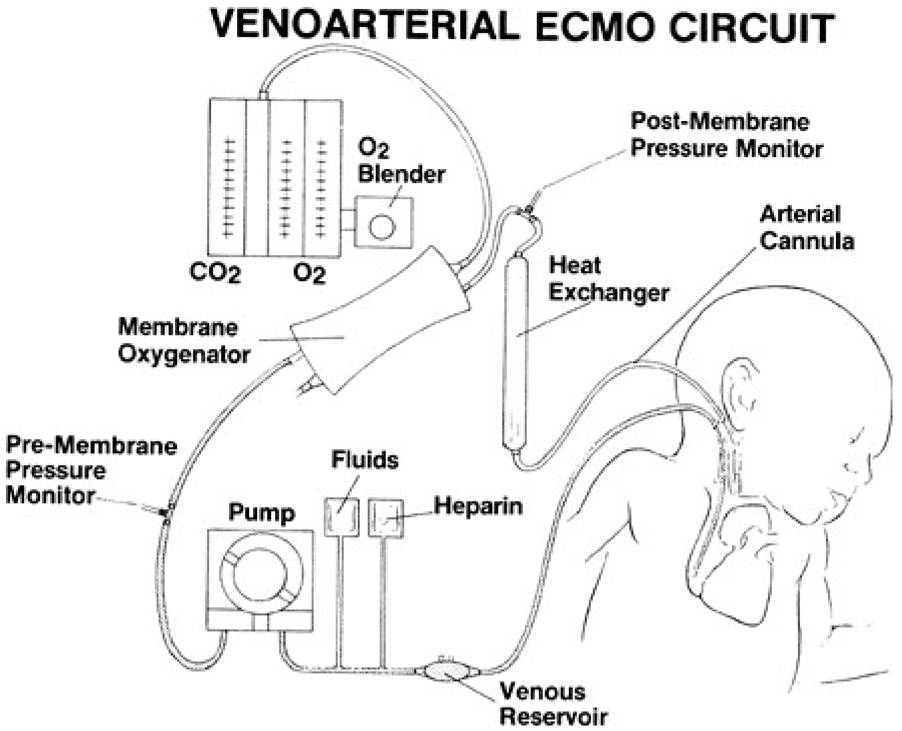
VENOARTERIAL ECMO CIRCUIT
O2 Blender
Post-Membrane Pressure Monitor
Arterial Cannula
CO2
O2
Heat Exchanger
Membrane Oxygenator
Pre-Membrane Pressure Monitor
Fluids
Pump
Heparin
Venous Reservoir

FIG. 32.1. Schematic diagram of venoarterial extracorporeal membrane oxygenation circuit, showing the drainage from the right atrium into the bladder of the circuit, with flow through the membrane lung, heat exchanger, and return flow to the arch of the aorta via the carotid artery catheter. (From Polin RA, Fox WC, eds. Fetal and Neonatal Physiology, Vol. 1. Philadelphia: WB Saunders; 1992:933, with permission.)

- Surgical instruments required are listed in Tables 32.1 and 32.2.
- Sterile gowns and gloves
- Sterile saline for injection
- Syringes (1 to 20 mL) and needles (19 to 26 gauge)
- Povidoneâ€“iodine solution
- Povidone iodine ointment
- Semipermeable transparent membrane-type dressing
- Absorbable gelatin sponge, for example, Gelfoam (Upjohn, Kalamazoo, MI, USA)
- Surgical lubricant, bacteriostatic

Nonsterile

- Surgical head covers and mask
- Pulse oximeter
- Surgical head light
- Electrocautery
- Wall suction
- Shoulder roll, for example, a small blanket, to place under infant's shoulders
- Tubing clamps

Medications

- A long-acting paralyzing agent, for example, pancuronium bromide (0.1 mg/kg)
- Fentanyl citrate (10 to 20 mcg/kg)

- Sodium heparin (75 to 150 U/kg)
- Topical thrombin/Gelfoam
- Xylocaine, 0.25%, with epinephrine
- Xylocaine, 1%, plain (without epinephrine)
- Cryoprecipitate, thawed, or commercially available fibrin sealant (optional)

TABLE 32.1 Surgical Instruments for ECMO Cannulation

Number	Item
Place in a 12 - 18-in mayo tray with a Huck towel on the bottom of the tray.	
2	Custard cup (place on inside of other cup with a 3 - 4-in sponge)
1	Medicine cup (place inside of custard cup with a 3 - 4-in sponge)
2	Straight bulldog clamps
1	Sauer eye retractor
1	Alm retractor
1	Mastoid Jansen retractor
2	Vein retractors
2	Octagonal forceps
2	7-in Gerald forceps
2	6-in DeBakey forceps
1	Adson forceps, plain
2	Adson forceps with teeth
2	No. 3 knife handles
1	Castroviejo needleholder
2	Right-angle retractors
2	Chops retractors
1	Set of Garrett dilators, nine pieces (sizes 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0)
String the following instruments from left to right on two 9-in sponge sticks or instrument stringer. Then place on top of a rolled Huck towel.	
4	9-in sponge stick
1	Tonsil clamp (bleeder)
1	612-in crile
1	534-in crile
1	Baby right-angle clamp
4	Straight mosquitoes
6	Curved mosquitoes
3	Fine curved mosquitoes
2	Tubing clamp with guard
1	Ryder needleholder
1	Webster needleholder
1	Straight mayo scissor
1	534-in Metzenbaum scissor
1	Curved Steven scissor
1	Straight Iris scissor
4	Small towel clips (nonpenetrating)
1	Baby Satinsky clamp
1	Curved bulldog clamp
1	Straight bulldog clamp
1	Disposable ECMO tray (Table 32.2)

ECMO, extracorporeal membrane oxygenation. For information on suture material, see Appendix B2.

TABLE 32.2 Contents of Disposable Extracorporeal Membrane Oxygenation Tray

Number	Item
2	1-mL syringe
1	20-mL syringe
1	6-mL syringe
1	3-mL syringe
1	Needle adapter
3	Single-cavity tray
2	Gauze packages
1	Betadine ointment
1	Surgical blade no. 15 carbon
2	Semipermeable transparent dressings
1	Handle, suction frazier, 8 Fr
1	Xylocaine insert
1	Mini yellow vessel loops
1	Hand-control cautery
1	Suture, 4-0 Vicryl
1	Suture, 2-0 silk
1	Suture, 6-0 Prolene
4	Forceps, sponge
1	25-gauge needle
1	NaCl, 5-mL amp
1	3-g foil package of Surgilube
1	Surgical blade, no. 11 carbon
2	Steri-Drapes
2	Connectors, straight 14 — 14 in
1	Xylocaine 1%
1	Suction tubing, 316 in — 10 ft
1	Package sterile towels (14)

E. Technique Preparation for Cannulation

- Place infant with head to foot of warmer.
- Anesthetize the patient with fentanyl (10 to 20 mcg/kg).
- Paralyze the patient with pancuronium (0.1 mg/kg).
- Hyperextend the patient's neck with a shoulder roll, and turn the head to the left (Fig. 32.2). Make sure that the Bovie ground pad is placed at this time.

  Observe closely for hypotension.

- Monitor vital signs and give additional fentanyl and/or pancuronium as needed (see Chapter 5).
- Clean a wide area of the right neck, chest, and ear with Betadine solution.
- Drape the infant and entire bed with sterile towels.
- Use Steri-Drapes (3M Health Care, St. Paul, MN, USA) to secure the towels to the skin.

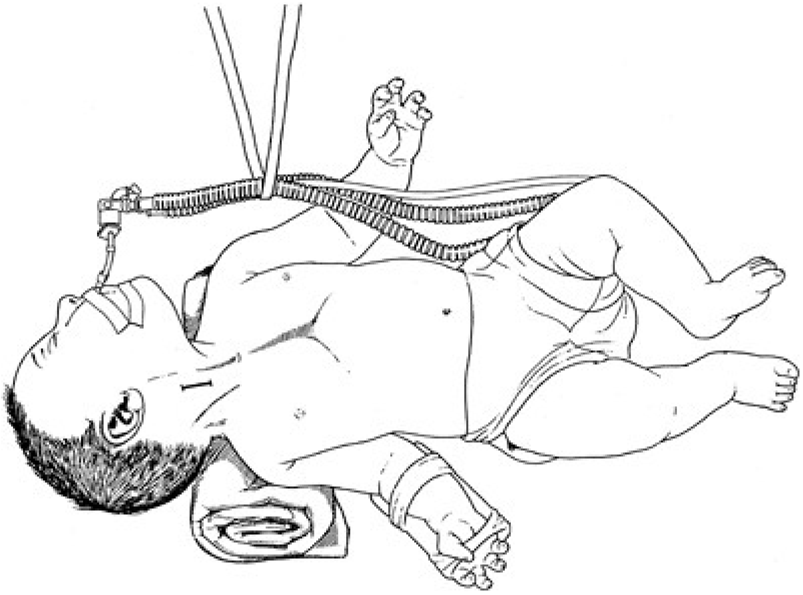

FIG. 32.2. Infant positioned for cannulation with shoulder roll present and head extended to the left. Position of neck incision is indicated.

- At the point of incision, infiltrate the skin with Xylocaine (AstraZeneca, Wayne, PA, USA) (0.25%, with epinephrine) (Fig. 32.2).
- Wait at least 3 minutes for anesthesia to be effective.
- Make a 1- to 2-cm vertical incision over the right sternocleidomastoid muscle, starting approximately 1 cm above the right clavicular head, using the electrocautery set on cutting current (Fig. 32.3).
- Continue to use the electrocautery to cut through the subcutaneous tissue.

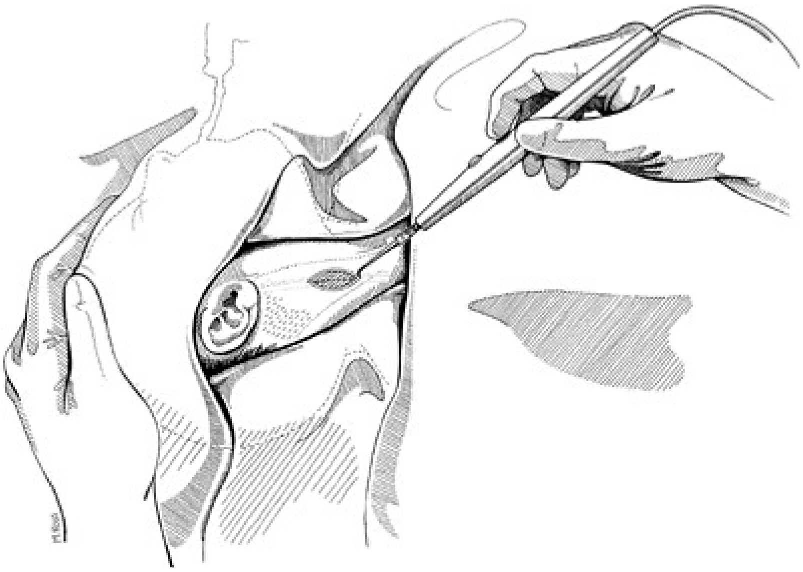

FIG. 32.3. Landmarks over the sternocleidomastoid muscle for making the incision with electrocautery.

- Coagulate all visible bleeding sites.
- Spread the fibers of the sternocleidomastoid muscle apart with a hemostat and retract using hemostats clamped onto the muscle (Fig. 32.4).
- Open the carotid sheath, taking care to avoid the vagus nerve.

- Irrigate both the common carotid artery and internal jugular vein with 1% plain Xylocaine to vasodilate the vessels.

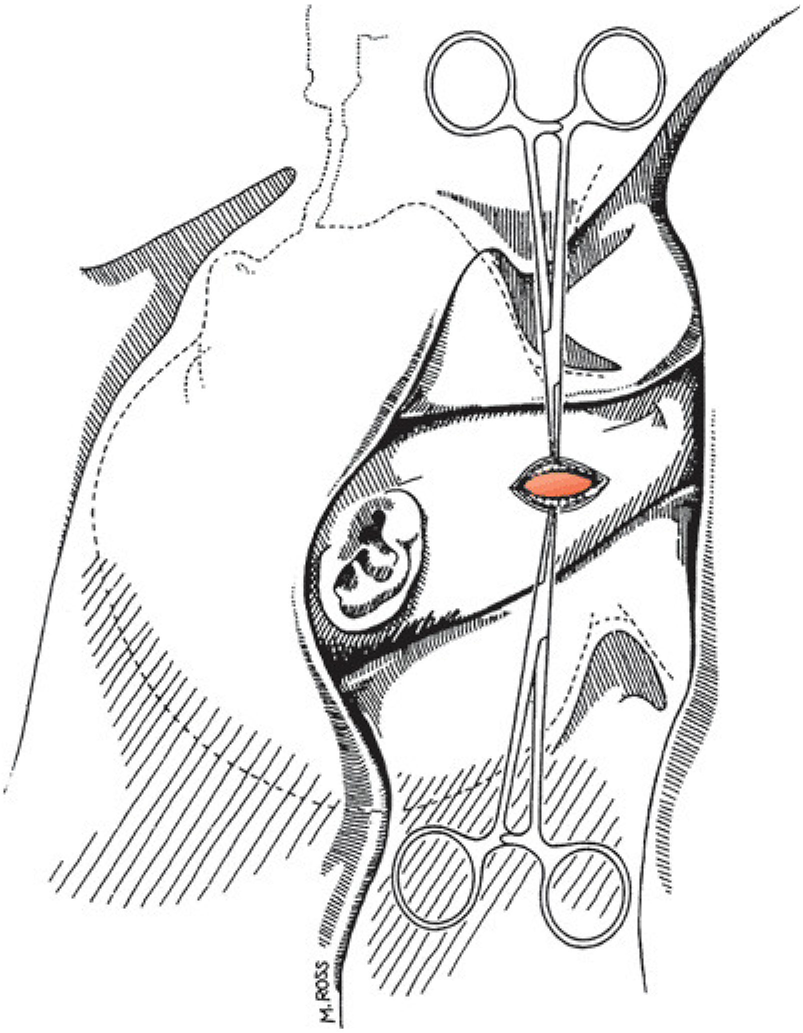

FIG. 32.4. Split sternocleidomastoid and open carotid sheath.

- Encircle the artery with silicone loop, and proximal and distal 2-0 silk ties held with clamps but not tied. Avoid â€œsawingâ€□ the ties on the artery.
- Avoid excessive handling of the internal jugular vein. Some isolate the vein after cannulation of the carotid artery to avoid spasm.
- Estimate the length of the cannula to be inserted.
    - Identify the sternal notch and the xiphoid process.
    - The arterial catheter is inserted approximately one third of the distance between the sternal notch and the xiphoid process. This is typically between 3 and 4 cm.
    - The venous catheter is inserted approximately one half the distance between the sternal notch and the xiphoid process. This is typically between 7 and 7.5 cm.
    - Mark these distances on the catheters with a 2-0 tie, or note the distance if the cannula is marked.
    - Heparinize the patient with a bolus of 75 to 150 U/kg of heparin, depending on the estimated risk of bleeding, and wait 60 to 90 seconds before proceeding with cannulation.

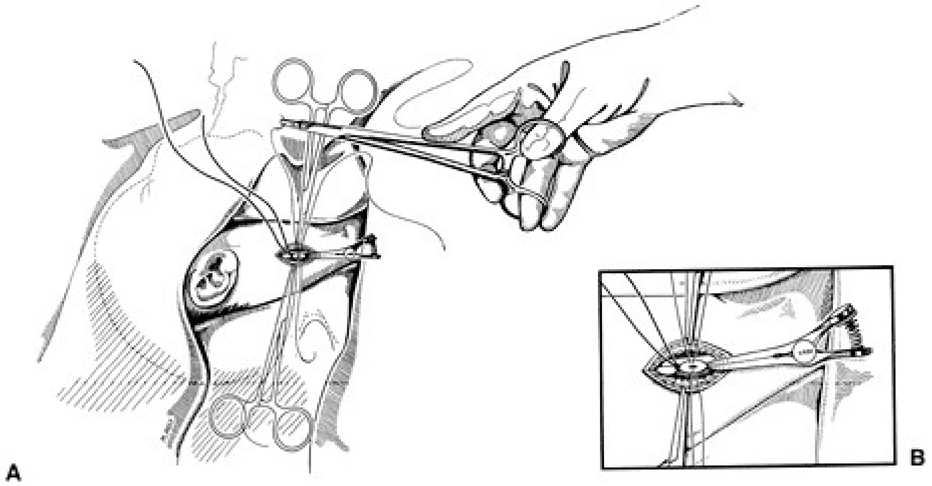

FIG. 32.5. A: Carotid artery isolated with vessel clamp in place and with arteriotomy site showing the placement of the 6-0 Prolene traction sutures. B (inset): Magnified view of (A).

Arterial cannulation

- Tie the distal ligature on the carotid artery, and place a bulldog clamp on the proximal portion of the artery.

  Allow blood to dilate the artery before placing the bulldog clamp.

- Make an arteriotomy using a no. 11 scalpel blade, and place two traction sutures of 6-0 Prolene (Ethicon, Somerville, NJ, USA) on the proximal side of the arteriotomy (Fig. 32.5).

  Always use traction sutures, to prevent intimal tears.

- If desired, lubricate Garrett dilators with sterile surgical lubricant and dilate the artery to the approximate size of the catheter.
- Place a sterile tubing clamp on the catheter. Lubricate the catheter and insert the catheter into the vessel as the bulldog clamp is removed.
- Secure the catheter with a 2-0 silk ligature tied over a 0.5- to 1-cm vessel loop (â€œbootieâ€□) (Fig. 32.6).
- Place a second 2-0 silk ligature. Tie the distal tie around the catheter, and then tie the distal and proximal ties together. Some surgeons place two ties proximally and one distally for added security.
- Allow blood to back up into the catheter to remove air.

Venous cannulation

- Dissect the vein free and isolate with two 2-0 silk ties.

  Do not apply traction to the vein with the ties, to avoid spasm.

- Place a bulldog clamp on the proximal end of the vein, allowing blood to distend it. Then tie the distal end of the vein with the 2-0 silk ligature.
- Make a venotomy with a no. 11 scalpel blade, and place two stay sutures of 6-0 Prolene as traction sutures, as for arterial cannulation.
- Lubricate the venous catheter, place a sterile tubing clamp on the catheter, and dilate the venotomy.

- Insert the catheter as an assistant places traction on the proximal tie, and apply pressure over the liver to increase the backflow of blood out of the catheter (to decrease the risk of an air embolus).

  There will be a slight impedance to catheter advancement at the thoracic inletâ€”pushing against resistance will tear the vein. Use gentle downward and posterior pressure.

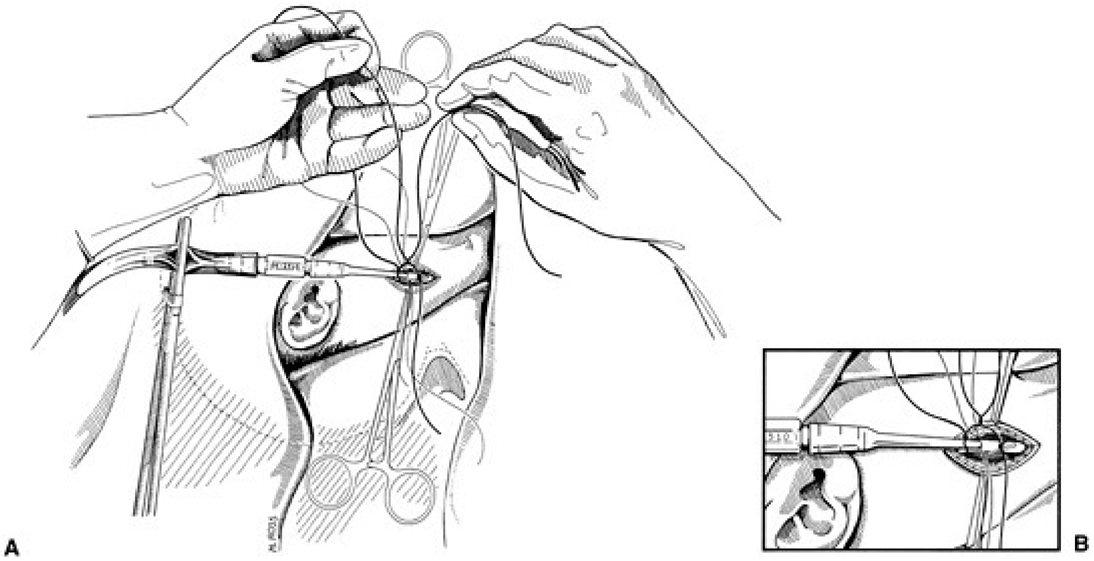

FIG. 32.6. A: Securing the catheter with proximal and distal ties onto a â€œbootie.â€□ B (inset): Magnified view of (A).

- Secure, as for the artery, and back blood into the catheter by pressing gently on the liver.
- If desired, pack the wound with absorbable gelatin sponge soaked in topical thrombin or commercially available topical fibrin sealant, to assist in hemostasis.

  Cryoprecipitate and topical thrombin can be used to form a fibrin clot if dropped onto the field from separate syringes in a one-to-one concentration. Note: If they are mixed together in one syringe, they will form a solid clot in the syringe. A similar product is now commercially available as Tisseel-HV Fibrin Sealant (Baxter Hyland Division, Glendale, CA, USA).

- Confirm catheter placement by chest radiography and/or cardiac echocardiography, if the patient is stable (Fig. 32.7) (10). If the patient is unstable, he or she can be placed on ECMO and the radiograph taken when adequate oxygenation is achieved but prior to closing the surgical wound.

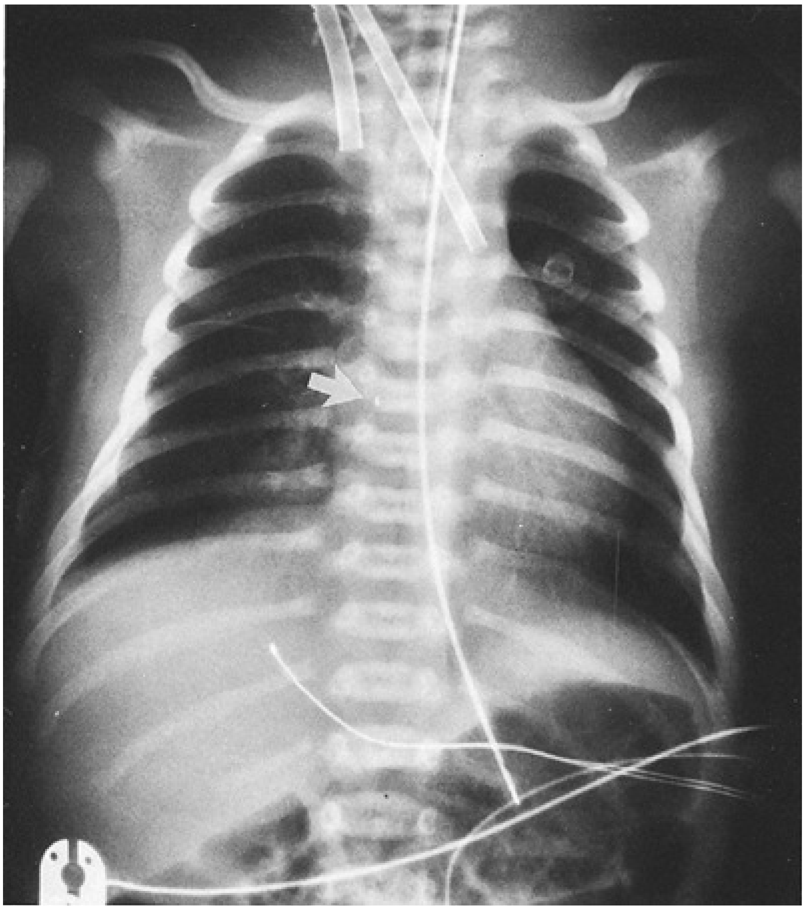

FIG. 32.7. Radiograph at cannulation, showing proper placement of the arterial and venous catheters. Note the radio-opaque dot indicating the end of the Bio-Medicus venous extracorporeal membrane oxygenation catheter (arrow).

Venovenous Extracorporeal Membrane Oxygenation Cannulation

More than 60% of neonatal ECMO patients reported in the ELSO registry have received treatment with venoarterial bypass (11). In neonates with respiratory failure, venoarterial ECMO is gradually being replaced by a venovenous (VV) technique, which uses a single double-lumen catheter (Fig. 32.8). The catheter is placed in the right atrium, where blood is drained and reinfused into the same chamber, thus requiring cannulation of only the right jugular vein, thus sparing the carotid artery. Other advantages of VV ECMO include maintenance of normal pulsatile blood flow, and the theoretical advantage that particles entering the ECMO circuit enter by way of the pulmonary rather than the systemic circulation. The design of the original VV catheter resulted in significant recirculation, limiting its use when ECMO flows >350 mL/min were required. Research by Rais-Bahrami et al. resulted in development of a new catheter design that significantly lowers the degree of recirculation (12). The double-lumen catheter should be placed within the right atrium, directing the oxygenated blood from the return lumen through the tricuspid valve to minimize recirculation. This catheter design in 12-, 15-, and 18-Fr sizes allows the use of VV ECMO in a greater number of infants (13).

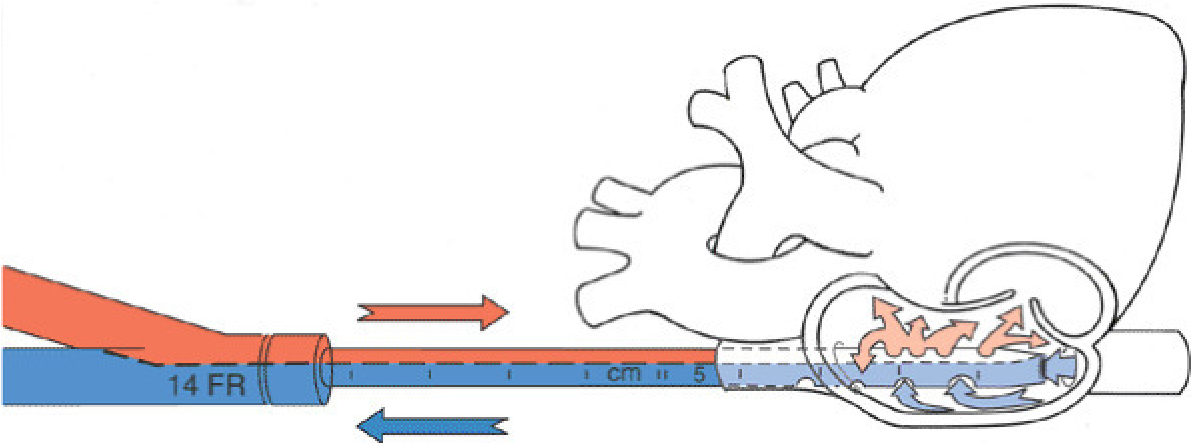

FIG. 32.8. Schematic of the venovenous extracorporeal membrane oxygenation catheter placed in the mid-right atrium. (From Short BL. CNMC ECMO Training Manual. 2005, with permission).

A. Double-Lumen Venovenous Catheters

- Kendall 14-Fr catheter (Kendall Health Care Products, Mansfield, MA, USA)
- OriGen 12-, 15-, and 18-Fr catheters (OriGen Biomedical, Austin, TX, USA)

B. Advantages of Venovenous Bypass

- Provides excellent pulmonary support
- Avoids carotid artery ligation
- Oxygenated blood enters pulmonary circulation.
- Particles coming from the ECMO circuit enter the venous circulation instead of the arterial circulation.

C. Disadvantages of Venovenous Bypass

- Lack of cardiac support
- ECMO support is dependent on the patient's cardiac function.
- Catheter position and rotation are extremely critical.
- Amount of recirculation

D. Cannulation Technique

The cannulation technique for venovenous ECMO is essentially the same procedure as venous cannulation for venoarterial ECMO, with the following exceptions:

- Both internal jugular vein and carotid arteries are identified and dissected free, although the internal jugular vein is the only vessel cannulated with the double-lumen venovenous catheter. A silastic loop may be tied loosely around the artery to facilitate potential conversion to venoarterial flow.

  Both vessels are isolated in case a rapid conversion to venoarterial bypass becomes necessary.

- The catheter is advanced in a direction with the arterial side upward and anterior to the venous limb of the double-lumen cannula.

Caution: Avoid bending the catheter or creating a â€œcrimpâ€□ in the catheter.

Correct positioning of the catheter helps direct the oxygenated blood return toward the tricuspid valve, thus minimizing the recirculation of the oxygenated blood back to the ECMO circuit.

- The proximal end of the internal jugular vein is also cannulated for cephalad drainage, that is, a jugular bulb catheter. This catheter is connected to the venous tubing of the ECMO circuit via a Luer connector. For this, we use a custom-made Carmeda heparin-coated Bio-Medicus venous catheter, made specifically for use as a cephalad catheter.

  This allows additional venous drainage to the ECMO circuit, prevents venous congestion, and also allows for cephalic venous saturation measurement.

- If using a jugular bulb catheter to measure cerebral saturations, care should be used when entering the circuit; air will draw into the venous side of the circuit rapidly if a stopcock is loose or is left open.

E. Placing Patient on the Extracorporeal Membrane Oxygenation Circuit

The circuit has been previously primed with packed cells/albumin. The priming procedure and the surgical placement of the ECMO catheters should be timed so that the two are completed at the same time. Priming of the circuit is beyond the scope of this chapter.

- Fill catheters with sterile saline. Connect them to the ECMO circuit by inserting the Â¼XÂ¼-in connectors into the tubing as the assistant drips sterile saline into the ends of the circuit tubing and the catheter, to ensure that all residual air is eliminated prior to connection.
  - Do not squeeze the tubing while attaching; air will enter when the tubing is released.
  - If air is seen in the tubing, the catheters must be disconnected from the circuit. Prior to reconnection, air is removed, and the catheters are reconnected as described in E.1.
- Remove all sterile tubing clamps from the catheters, and have a nonsterile assistant hold the catheters. Nonsterile tubing clamps remain in place on the arterial and venous sides of the circuit at this juncture.
- Place the patient on ECMO by removing the arterial clamp, placing a clamp on the bridge (Fig. 32.9a), and removing the venous clamp. This will remove all nonsterile clamps from the circuit.
- Increase ECMO flow in 50-mL increments over 20 to 30 minutes, until adequate oxygenation is achieved (usually at 120 mL/kg/min).

  Transfusion may be needed if hypotension occurs at this stage.

- Decrease the ventilator settings and oxygen concentration gradually as the ECMO flows are increased.

  Typical resting ventilator settings for venoarterial ECMO are at a rate of 10 to 15 breaths/min, a peak pressure limit of 15 to 20 cm H_2O, and F_iO_2 of 0.21 to 0.30. For venovenous ECMO, it is recommended to keep ventilator settings at a rate of 20 to 30 breaths/min, a peak inspiratory pressure of 20 to 25 cm H_2O, and F_iO_2 of 0.30 to 0.50.

F. Closure of the Neck Wound

- Obtain radiographic confirmation of appropriate catheter position and achievement of an adequate flow rate through the ECMO circuit prior to closure of the neck wound.

- Cut and remove traction sutures.
- Approximate the skin with a running 4-0 Vicryl (Ethicon) suture on an atraumatic needle.
- Tie the Vicryl suture, and use the tails of the suture to secure each catheter.
- Tie catheters together with another silk tie.
- Anesthetize the area behind the ear with 0.25% Xylocaine with epinephrine.
- Use 2-0 silk suture on a noncutting needle to place a stitch behind the ear and tie around the catheter to secure in place. Place a separate stitch for each catheter.
- Tie catheters together, dress the incision with povidoneâ€“iodine ointment, and cover the area with semipermeable membrane dressing.
- Tape the circuit tubing securely to the bedside to reduce traction on the catheters.

G. Complications

- Torn vessels, more commonly the vein
    - This risk is decreased if 6-0 Prolene stay sutures are always used.
    - Do not attempt to use too large a catheter.
- Aortic dissection associated with arterial cannulation (14)
- Blood loss, particularly during the venous cannulation, when side holes in the catheter are outside the vein
- Venous spasm, resulting in inability to place a large enough venous catheter to meet the required ECMO flow to support the patient adequately

  The rate of blood flow is impeded by the small gauge of the catheter, requiring that a second venous catheter be placed in the femoral vein. The two catheters must be Y-connected together into the ECMO circuit.

- Arrhythmias and/or bradycardia can occur, owing to stimulation of the vagus nerve
- Hypotension, due to an increase in the intravascular space when the patient is connected to the ECMO circuit
- Conversion to venoarterial from venovenous ECMO. This will occur if:
    - The patient remains hypoxic despite adequate ECMO flow.
    - The patient remains hypotensive despite vasopressor support.
    - Cerebral venous saturations remain persistently <60% after adequate flows and ventilator management have been undertaken.

      Converting from venovenous to venoarterial ECMO requires cannulation of carotid artery with a Biomedicus arterial catheter, and the double-lumen venovenous catheter must be â€œY'dâ€□ in together to make a double-lumen venous drainage catheter (Fig. 32.9).

Extracorporeal Membrane Oxygenationâ€"Decannulation

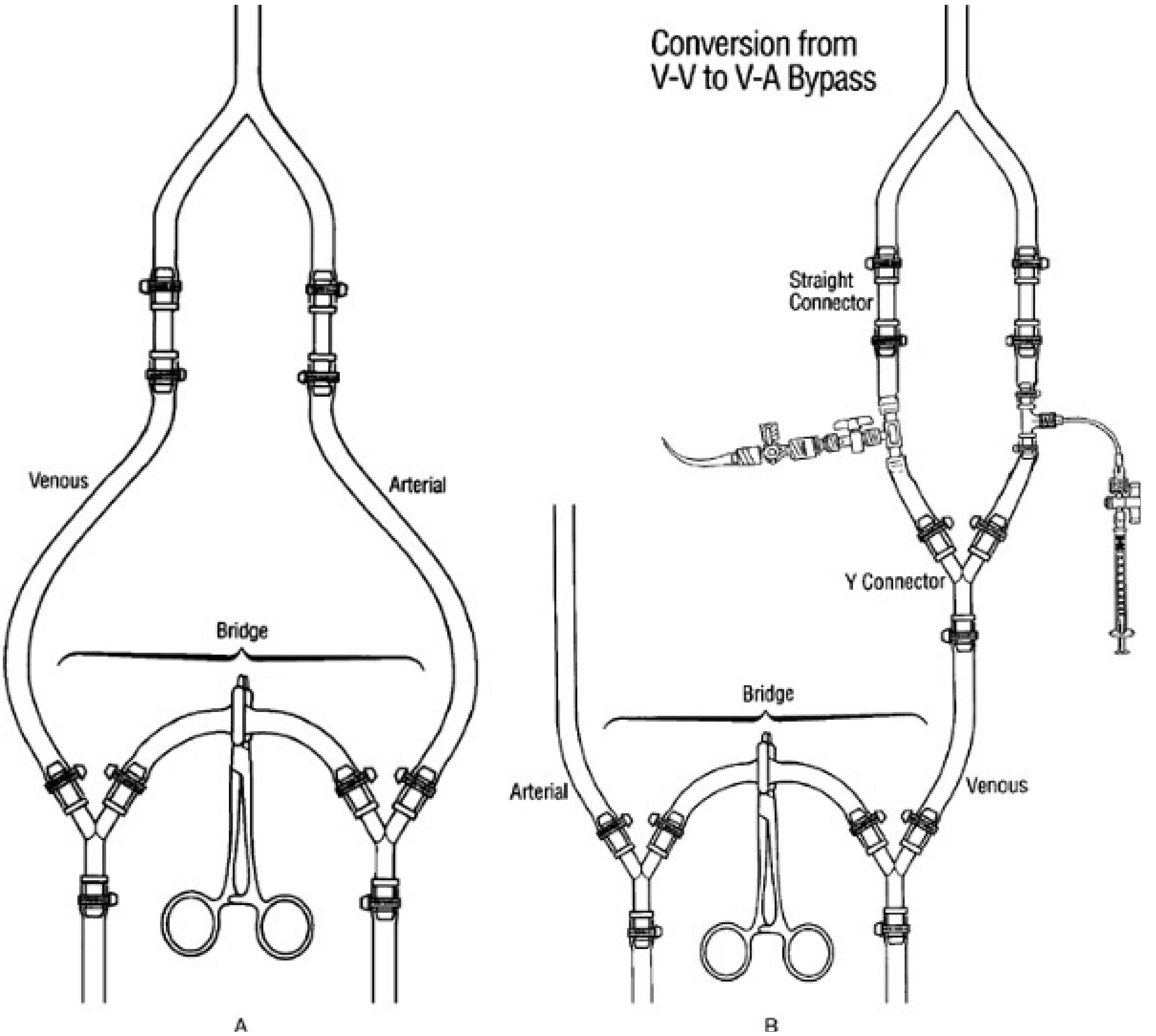
Conversion from
V-V to V-A Bypass
Venous
Arterial
Bridge
Straight Connector
Y Connector
Bridge
Arterial
Venous
A
B

FIG. 32.9. Schematic view of converting from venoarterial (A) to venovenous (B) ECMO. The double-lumen venovenous catheter is â€œY'dâ€□ together to make a double-lumen venous drainage catheter.

A. Indications

- Removal from ECMO after lung recovery
- Removal from ECMO because of a complication such as uncontrolled bleeding or failure of lung recovery

B. Contraindications

All intensive support is being withdrawn, and permission for autopsy is obtained. It is usually optimal to remove the catheters during the autopsy.

C. Precautions

- The patient must be paralyzed during the removal of the venous catheter to avoid an air embolus.
- The vessels are fragile and may tear. A backup unit of blood should be available at the bedside.
- Delay removing catheter for 12 to 24 hours in cases in which there is a high risk of reoccurrence of pulmonary hypertensionâ€”for example, severe congenital diaphragmatic hernia.

D. Personnel, Equipment, and Medications

Personnel

Same as for cannulation, with the exception of the primer, which is not required

Equipment

Sterile

- Surgical tray with towels and suture as for cannulation
- Semipermeable transparent dressing
- Povidoneâ€““iodine ointment
- Syringes (1 to 20 mL) and needles (18 to 26 gauge)
- Unit of blood
- Absorbable gelatin sponge

Nonsterile
Same as for cannulation

Medications

- Fentanyl (10 to 20 mcg/kg)
- Vecuronium bromide (0.2 mg/kg)

  A short-acting paralyzing agent is preferred because of the relatively short duration of the procedure. This allows the infant to breathe spontaneously as soon as possible after decannulation, which facilitates rapid weaning from ventilator support.

- Xylocaine, 0.25%, with epinephrine
- Topical thrombin
- Protamine sulfate (1 mg only)

E. Technique

Postdecannulation vessel reconstruction is beyond the scope of this chapter.

- Place the neck in an extended position, using the shoulder roll.
- Give fentanyl for relaxation, prior to giving vecuronium.

  Because of the risk of air embolism during the removal of the venous catheter, the infant must not be allowed to breathe during decannulation. If two doses of vecuronium do not produce paralysis, give pancuronium.

- Increase ventilator setting to a rate of 40 to 50 breaths/min, a peak inspiratory pressure of 20 to 25 cm H_2O (depending on chest movement), and F_iO_2 of 0.30 to 0.40 after paralytic agent is given.
- Clean the neck, and drape as for cannulation.
- Anesthetize with 0.25% Xylocaine with epinephrine.
- Cut and remove the Vicryl suture.
- Remove absorbable gelatin sponge packing, exposing the catheters and vessels.

If a jugular bulb catheter is in place, it is usually removed first to allow better visualization for removal of the venovenous ECMO catheter.

- The jugular bulb catheter should be clamped off before its removal, after the patient is taken off bypass. Be aware that removing the catheter while on bypass without a clamp in place will result in the introduction of air into the circuit.

In case of venoarterial ECMO, the venous catheter is usually removed first because it is most readily accessible.

- Separate the catheter from surrounding tissue by blunt dissection.
- Encircle the vein with a 2-0 silk tie, which is used for traction and hemostatic control.
- Place a Satinsky clamp around the vein to stabilize the catheter (Fig. 32.10).
- Place a 2-0 silk tie proximal to the clamp.
- Cut the silk ties securing the catheter in the vein with a no. 11 scalpel blade. The two proximal ties should be cut where they cross the vessel loop (â€œbootieâ€□).
- Ask the ECMO specialist to remove the patient from the ECMO circuit.
- Monitor vital signs and oxygen saturation as an indication that ventilator settings are appropriate. Settings may have to be increased when the patient is removed from the circuit.
- Provide an inspiratory â€œholdâ€□ on the ventilator while the surgeon places pressure on the liver and removes the catheter. Failure to do this can result in air embolus.
- Replace any significant blood loss.
- Cut the 2-0 silk traction suture and tie the suture proximal to the Satinsky clamp. Remove the Satinsky clamp.
- Isolate the arterial catheter, dissect free, and remove.

The decannulation procedure is the same as for the arterial catheter, with the exception that an inspiratory hold is not required.

- Give protamine (1 mg IV) after removal of both catheters.

Administration of protamine is not mandatory if there is no significant bleeding.

- Irrigate the wound with sterile saline and cauterize any bleeding sites.
- If desired, pack the wound with a thrombin-soaked absorbable gelatin sponge and close the neck incision using subcuticular horizontal sutures of 4-0 Vicryl.
- Remove the sutures holding the cannula behind the right ear.
- Place povidoneâ€“iodine ointment over the incision and cover with semipermeable transparent dressing.

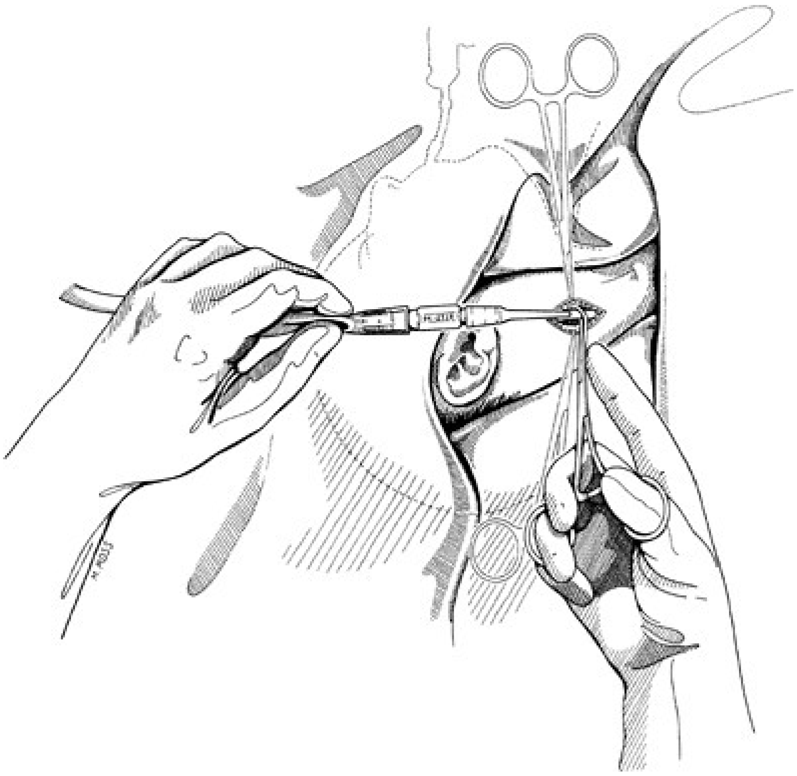

FIG. 32.10. Placement of Satinsky vessel clamp prior to removal of extracorporeal membrane oxygenation catheter.

F. Complications

- Vessel laceration, which may require a sternotomy for correction
- Excessive blood loss
- Venous air embolus

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33-Management of Vascular Spasm and Thrombosis

Jayashree Ramasethu

Thromboembolism (TE) is being increasingly recognized as a significant complication of intravascular catheters in sick newborn infants. About 90% of neonatal venous thromboses are associated with central venous catheters, although additional risk factors may be present (1). This chapter focuses on catheter-related vascular spasm and thrombosis.

A. Definitions

- Vascular spasm is transient, reversible arterial constriction, triggered by intravascular catheterization or arterial blood sampling. The clinical effects of vascular spasm usually last less than 4 hours from onset, but the condition may be difficult to differentiate from more serious thromboembolic (TE) disease. The diagnosis of vasospasm of arteries may only be made retrospectively, after documentation of the transient nature of ischemic changes and complete recovery of circulation.
- Thrombosis is the complete or partial obstruction of arteries or veins by blood clot(s).

B. Assessment

- Clinical diagnosis (Fig. 33.1)
  - The clinical signs associated with arterial or venous TE are shown in Table 33.1.
  - Vascular spasm of peripheral arteries is characterized by transient pallor or cyanosis of the involved extremity with diminished pulses and perfusion.
  - Persistent bacteremia or thrombocytopenia are nonspecific signs associated with vascular thrombosis at any site.
  - Clinical signs may be subtle or absent in many cases of thrombosis.
- Diagnostic imaging
  - Contrast angiography is the â€œgold standard.â€ It gives the best definition of thrombosis, but it is difficult to perform in critically ill neonates and requires infusion of radiocontrast material that may be hypertonic or cause undesired increase in vascular volume (2).
  - Doppler ultrasonography is portable, noninvasive, and can be used to monitor progress over time. It is useful for follow-up of aortic and peripheral arterial obstruction, but it may give both false positive and false negative results compared with contrast angiography (3).
- Additional diagnostic tests
  - Obtain detailed family history in all cases of unusual or extensive TE.

  - In the absence of predisposing risk factor for thrombosis, consider investigations for the diagnosis of thrombophilic disorders: anticardiolipin, antithrombin III, protein C, protein S deficiency, etc. (4,5).

C. Management of Vascular Spasm

- Warm contralateral extremity (reflex vasodilation).
- Maintain neutral thermal environment for affected extremity, i.e., keep heat lamps away from the area.
- Maintain limb in horizontal position.
- If necessary, restore circulating volume with blood, albumin, or plasma.
- Consider removing catheter.

If mild cyanosis of the fingers or toes is noted after insertion of an arterial catheter, but peripheral pulses are still palpable, a trial of reflex vasodilation with close observation is reasonable, because vasospasm may resolve. Continually assess the need for keeping the catheter in place (i.e., the benefits of arterial access vs. the risk of thrombosis and further complications). A white or â€œblanchedâ€□-appearing extremity is an indication for immediate removal of the catheter.

- Topical nitroglycerine has been demonstrated to reverse peripheral and umbilical artery catheterâ€“induced ischemia in isolated case reports. Maintain good circulatory volume. Monitor for hypotension and be prepared to treat it immediately.
  - Topical application of 2% nitroglycerine ointment at a dose of 4 mm/kg body weight, applied as a thin film over the affected areas; may be repeated after 8 hours (6,7 and 8).
  - Application of a nitroglycerine patch has also been described (9).

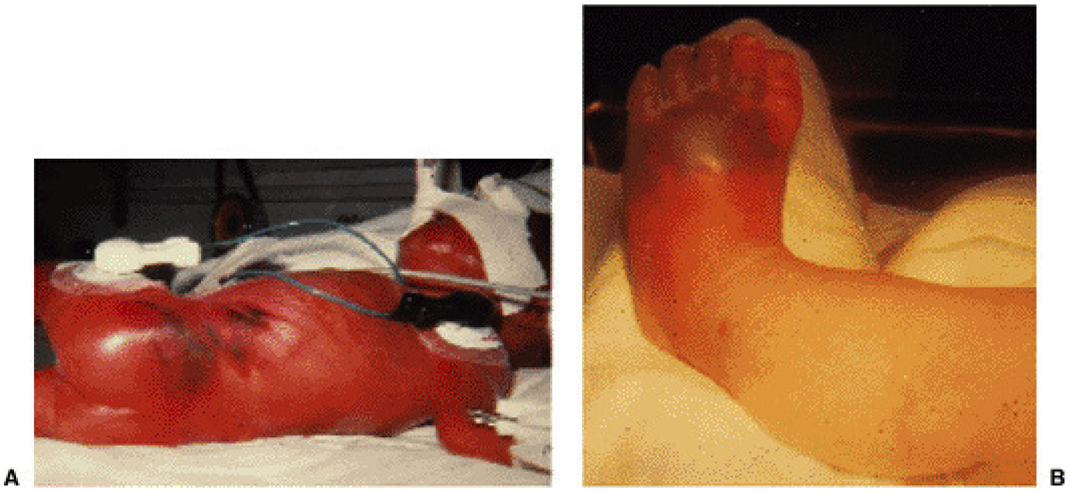

FIG. 33.1. Skin necrosis associated with an umbilical artery catheter. Such lesions develop after vasospasm or embolization. A: Spinal injury may be present when ischemia involves this region. B: The distal part of an extremity is a common site for embolic arterial loss. The full extent of loss is unpredictable at this stage. (From Fletcher MA. Physical Diagnosis in Neonatolgy. Phildelphia: Lippincott-Raven; 1998:127)

TABLE 33.1 Diagnosis of Vascular Thrombosis

Site	Clinical Signs	Diagnostic Imaging
CVL-associated venous thrombosis	Malfunction of CVL, SVC syndrome, chylothorax, swelling and livid discoloration of extremity, dilatation of collateral veins over trunk or abdomen in chronic cases	Contrast angiography Doppler ultrasonography
Inferior vena cava thrombosis	Lower limbs cool, cyanotic, edematous	Real time 2-D ultrasonography
Superior vena cava thrombosis	Swelling of upper limbs and head, chylothorax	
Renal vein thrombosis	Flank mass, hematuria, thrombocytopenia, hypertension	
Aortic or renal arterial thrombosis	Systemic hypertension, hematuria, oliguria	
Peripheral or central (aorta or iliac) arterial thrombosis	Pallor, coldness, weak or absent peripheral pulse(s), discoloration, gangrene	
Right atrial thrombosis	Congestive heart failure	Echocardiography
Pulmonary thromboembolism	Respiratory failure	Lung perfusion scan

CVL, central venous line; SVC, superior vena cava.

D. Management of Catheter-Related Thromboembolism

- General principles
  - Thrombolysis to restore catheter patency is described in Chapter 31.
  - Management of vascular TE may involve one or more of the following: supportive care, anticoagulation, fibrinolytic therapy, surgical intervention (4,5,10).
  - Treatment for neonates is highly individualized and is determined by the extent of thrombosis and the degree to which diminished perfusion to the affected extremity or organ affects function (4,5).
  - The infant should be managed in an appropriately staffed and equipped neonatal intensive care unit, where anticoagulant or thrombolytic therapy can be administered and monitored, and supportive and surgical care are readily available. Consultation with pediatric hematology is recommended. Plastic or vascular surgical consultation may be required.
  - The International Children's Thrombophilia Network, based in Canada, is a free consultative service, maintained 24 hours a day, for physicians worldwide who are caring for children with thromboembolic disease. The toll-free line in North America is 1-800-NO-CLOTS; the number for physicians elsewhere is 1-905-573-4795. The service provides current management protocols as well as links to the network and its services (11).
- Initial management
  - Initiate management as for vascular spasm for peripheral arterial ischemia.
  - Removal of catheter is advocated (5).

    Peripheral arterial and umbilical catheters should be removed immediately if an extremity appears white or â€œblanched.â€ Intravascular catheters are left in place even in the presence of thrombosis only if local thrombolysis through the catheter is planned (12).

  - Supportive care: correct volume depletion, electrolyte abnormalities, anemia, and thrombocytopenia; treat sepsis.

- Anticoagulant/thrombolytic therapy (4,5)

  The risk of serious bleeding associated with antithrombotic therapy in neonates must be balanced against the possibility of organ or limb loss or death without appropriate treatment. Adequate randomized controlled trials to guide therapy in neonates are not available (12,13). The following guidelines are based on published protocols used in small case series.

  - Contraindications
    - Major surgery within the last 10 days
    - Major bleeding: intracranial, pulmonary, or gastrointestinal
    - Pre-existing cerebral ischemic lesions
    - Relative contraindications: thrombocytopenia (platelet count <100 x 10^9/L), hypofibrinogenemia (fibrinogen <100 mg/dL), severe coagulation factor deficiency, hypertension. Anticoagulant/thrombolytic therapy may be given after correction of these abnormalities.
  - Precautions
    - No arterial punctures
    - No subcutaneous or intramuscular injections
    - No urinary catheterizations
    - Avoid aspirin or other antiplatelet drugs.
    - Monitor serial head ultrasound scans for intracranial hemorrhage.
  - Anticoagulants
    - Oral anticoagulants (Warfarin)

      Warfarin is not recommended in neonates because its anticoagulant effects are altered significantly by diet, illness, and other medications.

    - Standard or unfractionated heparin (14,15)
      - Anticoagulant, antithrombotic effect limited by low plasma levels of antithrombin in neonates
      - Dosage: Loading dose of standard heparin 75 U/kg IV over 10 minutes; maintenance dose 28 U/kg/hr for infants <1 year of age
      - Monitoring: Check activated partial thromboplastin time (APTT) 4 hours after loading dose and 4 hours after every change in the infusion rate.
        - Adjust heparin infusion to maintain APTT at 60 to 85 seconds, corresponding to an anti-FXa level of 0.3 to 0.7 U/mL.
        - If APTT <60 seconds, increase infusion rate by 10%, and repeat APTT after 4 hours.
        - If APTT >85 seconds, decrease infusion rate by 10%, and repeat APTT after 4 hours.
        - If APTT >96 seconds, hold heparin infusion for 30 to 60 minutes, and restart at lower infusion rate; repeat APTT after 4 hours.
        - When APTT values are therapeutic and infusion rate is stable, obtain complete blood count and APTT daily.
      - The optimal duration of anticoagulation with heparin is unknown, but therapy is usually continued for 5 to 14 days (4,5).
      - Monitor thrombus closely both during and following treatment.
      - Complications
        - Bleeding
        - Heparin-induced thrombocytopenia (16)
      - Antidote: Protamine sulfate IV may be used for rapid reversal of bleeding caused by heparin.

Dosage: 1.0 mg/100 U heparin received if the time since the last heparin dose is <30 minutes. The dose of protamine decreases linearly with increasing time since the last heparin dose, dropping to 0.25 mg/100 U heparin if the time since the last heparin dose is >120 minutes (5).

TABLE 33.2 Guidelines for Adjusting LMWH Treatment Dosage (32)

Anti-Factor Xa Level	**Dose Change**	**Repeat Anti-Factor Xa Level**
<0.35 U/mL	â†‘ by 25%	4 h following dose adjustment
0.35-0.49 U/mL	â†‘ by 10%	4 h following dose adjustment
0.50-1 U/mL	No change	Weekly, 4 h following a dose[a]
1.1-1.5 U/mL	â†“ by 20%	Before next dose and 4 h following dose adjustment
1.6-2.0 U/mL	Hold next dose for 3 h, then T by 30%	Before next dose and 4 h following dose adjustment
>2.0 U/mL	Hold dose until anti-factor Xa level 0.5 U/mL, then T by 40%	Q 12 h until anti-factor Xa level <0.5, then 4 h following reinstitution of therapy

[a] Check level 4 h after next dose if there is a change in renal function, addition of antibiotics, or if any bleeding occurs.

Modified from Andrew M, deVeber G. *Pediatric Thromboembolism and Stroke Protocols*. Hamilton, Ont.: B.C. Decker; 1999, with permission.

- Low-molecular weight heparin (LMWH) (17,18)
    - LMWHs have specific activity against factor Xa and less activity against thrombin, so therapy is monitored by anti-FXa assay and not by APTT.
    - Different LMWH preparations (e.g., enoxaparin, dalteparin, reviparin) differ in their molecular weights and dosage regimens.
    - Advantages: Subcutaneous administration.
    - Dosage: starting dose 1.5 mg/kg subcutaneously every 12 hours. Therapeutic dose range may vary from 0.95 to 3.5 mg/kg/12h.
    - Monitoring
        - Adjust dose to maintain anti-factor Xa level between 0.5 and 1 unit/mL (Table 33.2).
        - Although LMWHs have more predictable pharmacokinetics in adults, in neonates, prematurity, rapid growth, and liver and kidney dysfunction make dosage less predictable. Frequent adjustment of the dose is required to attain target anti-FXa levels.
        - Draw blood sample for testing from fresh venipuncture. There must be no contamination from standard heparin, e.g., from an arterial line.
        - Check levels 4 hours after subcutaneous administration of LMWH on day 1 and day 2 of treatment.
        - If therapeutic, weekly check of anti-factor Xa levels is adequate.
    - To discontinue anticoagulation, simply discontinue LMWH therapy. If an invasive procedure such as lumbar puncture is required, skip two doses of LMWH, and measure anti-factor Xa level prior to the procedure.
    - If an immediate antidote is required, protamine is partially effective. Consult a hematologist. 1 mg of protamine neutralizes 100 U (1 mg) of Enoxaparin given within the last 3 to 4 hours. Protamine should be administered IV, over a 10-minute period, as rapid infusions may produce hypotension.

- Thrombolytic agents
  - Thrombolytic agents should be considered in the presence of extensive or severe thrombosis when organ or limb viability is at risk.
  - Agents work by enhancing the conversion of plasminogen to plasmin, which then proteolytically cleaves fibrin within the clot to fibrin degradation products.
  - Supplementation with plasminogen in the form of fresh frozen plasma enhances the thrombolytic effect (19).
  - Thrombi that have been present for several days may be resistant to thrombolysis. Failure rates may be as high as 50% (20).
  - The administration of heparin, either concomitantly or following thrombolytic therapy, has not been adequately evaluated in neonates.
  - A wide variety of dosage protocols have been used (12).
    - Streptokinase
      - Associated with allergic reactions in adults and older children; replaced largely by urokinase. Limited information in neonates.
      - Dosage regimens in neonates range from 50 U/kg/hr (directly into the thrombus) to intravenous infusions of 2,000 U/kg/hr (5,21,22).
    - Urokinase
      - Nonantigenic, but like streptokinase, has a low affinity for plasminogen bound to fibrin (clot-bound fibrin).
      - Human-derived urokinase has been replaced by the recombinant form in the United States.
      - Dosage: Loading dose 4,400 U/kg over 20 minutes, followed by continuous IV infusion of 4,400 U/kg/hr for 6 to 12 hours (4,5). The dosage and duration of therapy is determined by the response. Doses up to 10,000 to 16,000 IU/kg/hr have been used (23). Smaller doses have been used for local treatment of thrombi without removal of central venous catheters.
    - Recombinant tissue plasminogen activator (r-tPA)
      - Nonantigenic, has specific affinity for plasminogen bound to fibrin, intensifying thrombolysis at the site of the clot; has a short half-life.
      - Large number of case reports published, with varying dosage protocols (17)
      - Dosage protocol 1: Infusion, 0.1 mg/kg/hr. If no response after 6 hours, may increase infusion rate by 0.1 mg/kg/hr every 6 hours, to a maximum of 0.5 mg/kg/hr. Monitor fibrinogen levels every 4 hours and keep levels >100 mg/dL (24).
      - Dosage protocol 2: Initial bolus, 0.1 mg/kg over 10 minutes, followed by infusion of 0.3 mg/kg/hr over a 3-hour period. Perform Doppler sonography at the end of each infusion. Fibrinogen assay 1 hour and 4 hours after each r-TPA infusion is initiated. If repermiabilization is not complete, up to four additional r-TPA infusions may be given at intervals of 12 to 24 hours (25).
      - Catheter-directed thrombolysis: Infusion of low doses of r-tPA through a catheter with the tip adjacent to or within the thrombus; higher response rate with decreased risk of bleeding (12).

        Initial bolus dose ranges from 0 to 0.5 mg/kg, followed by infusion of 0.015 to 0.2 mg/kg/hr.

    - Monitoring
        - Imaging studies every 4 to 12 hours during fibrinolytic therapy, to allow discontinuation of treatment as soon as clot lysis is achieved.
        - Measure thrombin time, fibrinogen and plasminogen levels, and fibrin split products or d-dimers prior to therapy, 3 to 4 hours after initiation of fibrinolytic therapy and one to three times daily thereafter (2).
        - Fibrinolytic response is measured by a decrease in fibrinogen concentration and increase in levels of fibrin degradation products, but the correlation between these hemostatic parameters and efficacy of thrombolysis is poor. Maintain fibrinogen levels of at least 100 mg/dL to prevent bleeding.

E. Complications of Anticoagulation/Fibrinolytic Therapy

- Hemorrhagic complications (12,26)
    - Intracerebral hemorrhage: Incidence approximately 1% in term neonates, 13% in preterm neonates, increasing to 25% in preterm infants treated in the first week of life. Data in preterm infants are confounded by the risk of â€œspontaneousâ€ intraventricular hemorrhage (26).
    - Other major hemorrhages: Gastrointestinal, pulmonary
    - Bleeding from puncture sites and recent catheterization sites
    - Hematuria
- Embolization

    Dislodgement of intracardiac thrombus, causing obstruction of cardiac valves or main vessels, pulmonary or systemic embolization (27,28).

F. Surgical Intervention (10,29,30and 31)
Early consultation is recommended, because surgical management may be required concomitantly, particularly for life- or limb-threatening emergencies.

- Thrombectomy
- Microvascular reconstruction
- Leech therapy
- Decompressive fasciotomy
- Mechanical disruption of thrombus using soft wires and balloon angioplasty in conjunction with continuous site-directed thrombolytic infusion into the clot.
- Amputation

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34-Endotracheal Intubation

Khodayar Rais-Bahrami

A. Indications

- When prolonged positive-pressure ventilation is required
- To relieve critical upper airway obstruction (Fig. 34.1)
- To provide a route for selective bronchial ventilation
- When tracheal suctioning is required to obtain direct tracheal culture
- To assist in bronchial hygiene when secretions cannot be cleared
- When diaphragmatic hernia is suspected

B. Contraindications

There is no absolute contraindication to intubating a neonate who has one of the above-mentioned indications. In older patients, the presence of cervical injuries is a contraindication to intubation with a laryngoscope; however, because the occurrence of cervical injuries is infrequent in neonates, we consider that endotracheal intubation is associated with less risk than performance of an emergency tracheotomy.

C. Equipment

The supplies and equipment necessary to perform endotracheal intubation should be kept together on either a resuscitation cart or an intubation tray. Each delivery room, nursery, and emergency room should have a complete set of the following items.

- Humidified oxygen/air source, blender, and analyzer
- Oxygen tubing
- Resuscitation bag and mask
- Suctioning device, with 10-French (Fr) suction catheters
- Cardiorespiratory monitor
- Pulse oximetry oxygen saturation monitor
- Stethoscope
- Gloves
- Scissors
- Sterile stylet
- Adhesive tape: Two 8- to 10-cm lengths of Â½-in-wide tape, with half the length split and one 10- to 15-cm length unsplit
- Magill forceps (optional for nasotracheal intubation)
- Pediatric laryngoscope with an extra set of batteries and extra bulb
    - Miller blade size 1 for full-term infant
    - Miller blade size 0 for preterm infant

Straight rather than curved blades are preferred for optimal visualization.

  - Modified blade to allow continuous flow of oxygen at 1 to 2 L/min for better maintenance of oxygenation during procedure (1)
- Endotracheal tubes with internal diameters of 2.5, 3.0, 3.5, and 4.0 mm
  - Diameter selected for infant size (Table 34.1)
  - Length selected for infant's size (2,3 and 4)

    In neonates, there is little leeway between a tube that is too high (increased risk for extubation) or too low (increased risk for mainstem intubation or airway trauma). The appropriate length for an endotracheal tube depends on a number of factors, including an infant's size, and it can be quickly and accurately estimated by measuring the nasalâ€“tragus length (NTL) and/or sternal length (STL). The modified prediction formula for insertion by the orotracheal route is NTL or STL + 1. For the nasotracheal route, the formula is NTL or STL + 2 (5).

    It is rarely necessary to insert a tube more than 1 to 2 cm below the vocal cords, regardless of the infant's size. Exceptions include the presence of anatomic defects that necessitate a â€œbypassâ€□ airway, such as a tracheal fistula or subglottic obstruction, and when selective bronchial intubation is intended (6). See Appendix D.

D. Precautions (Table 34.2)

- Select orotracheal route for all emergency intubations or when a bleeding diathesis is present. Reserve nasotracheal intubation for elective procedures after stabilization with orotracheal tube, unless oral anatomy precludes oral intubation.
- Prepare all equipment before starting procedure. Keep equipment ready at bedside of patients likely to require intubation.
- Use appropriate-size tubes (Table 34.1). The tube should not fit tightly between the vocal cords to minimize upper airway trauma.
- To minimize hypoxia, each intubation attempt should be limited to 20 seconds. Interrupt an unsuccessful attempt to stabilize the infant with bag-and-mask ventilation. In most cases an infant can be adequately ventilated by bag and mask, so endotracheal intubation can be achieved as a controlled procedure. The one important exception is in a case of prenatally diagnosed or suspected congenital diaphragmatic hernia.
- Recognize anatomic features of neonatal upper airway (Fig. 34.2).
- Ensure visualization of larynx. This is the most important step (Fig. 34.3).
  - Have assistant maintain proper position of patient.
  - Avoid hyperextending or rotating neck.

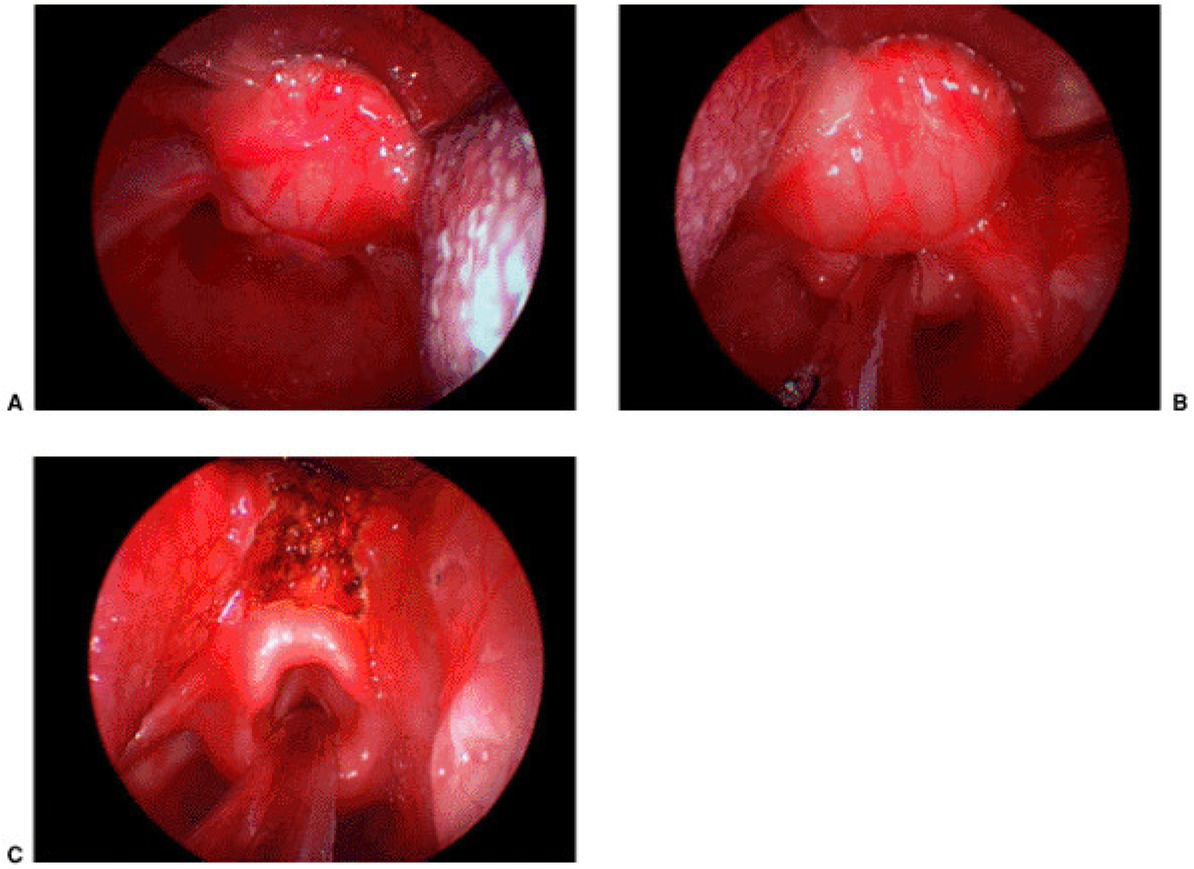

FIG. 34.1. A: Vallecula cyst, causing stridor and proximal airway obstruction. B: Endotracheal tube passes beneath cyst. C: Same patient after laser surgical treatment.

TABLE 34.1 Endotracheal Tube Diameter for Patient Weight and Gestational Age

Tube Size (ID mm)	Weight	Gestational Age
2.5	<1,000 g	<28 wk
3.0	1,000â€“2,000 g	28â€“34 wk
3.5	2,000â€“3,000 g	34â€“38 wk
4.0	>3,000 g	>38 wk

TABLE 34.2 Trouble-Shooting Problems with Endotracheal Intubation

Problem	Suggested Approach for Solution
Infant's tongue gets in way.	Push tongue aside with finger before inserting blade.
Secretions prevent visualization.	Suction prior to intubation attempt.
Tube seems too big to fit through vocal cord.	Verify correct tube size for patient weight and gestational age.
Vocal cords are closed.	Decrease angle of neck extension. Apply traction to blade. Select smaller tube size. Evaluate for airway stenosis.
Unsure of appropriate tube length.	Await spontaneous breath. Apply gentle suprasternal pressure.
Difficult to ventilate after intubation.	Insert tube just past vocal cord. Predetermine tube length. Obtain chest radiograph with head in neutral position to confirm tube position relative to carina.
Swelling of neck and anterior chest.	Verify that tube is in trachea. Verify that tube is not in bronchus. Consider tube and/or airway obstruction.
Blood return from endotracheal tube.	Evaluate for tracheal perforation.
Tube slips into main bronchus.	Avoid neck extension. Secure tape fixation. Maintain correct lip-to-tip distance.
Unplanned extubation.	Regularly verify correct tube distance. Secure tape and replace as necessary. Support neck when moving infant. Avoid neck extension or traction on tube. Secure infant's hands.

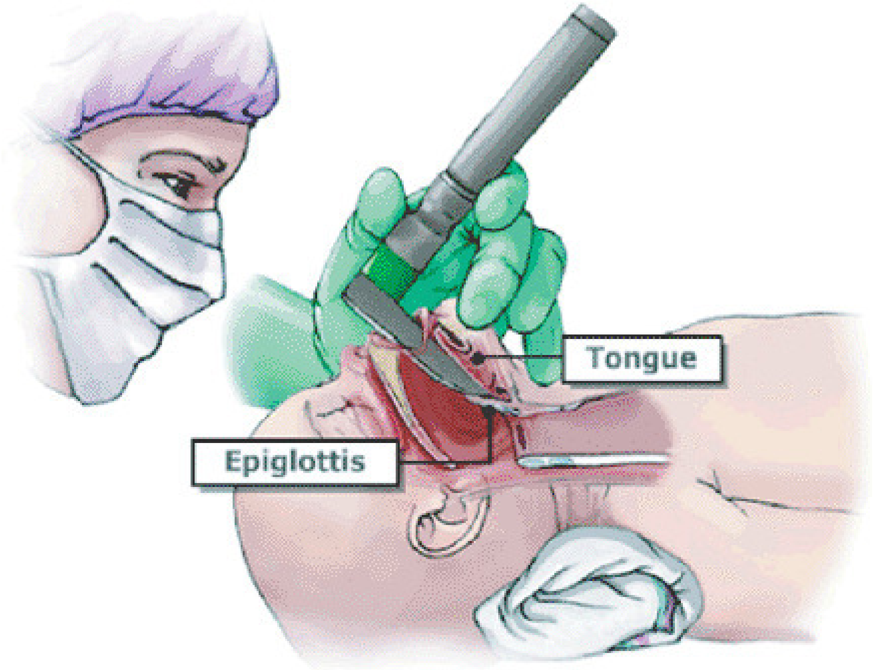

FIG. 34.2. Anatomic view of neonatal upper airway. The glottis sits very close to the base of the tongue, so visualization is easiest without extending the neck.

- Do not use pressure or force that may predispose to trauma.
    - Avoid using maxilla as fulcrum for laryngoscope blade.
    - Avoid excessive external tracheal pressure.
    - Avoid pushing tube against any obstruction.

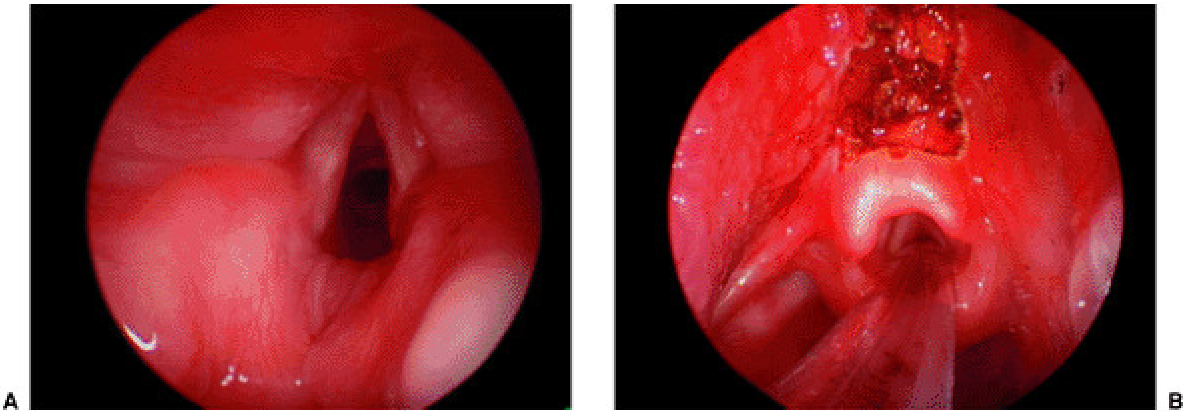

FIG. 34.3. A: Normal epiglottis obscuring glottis. This amount of clear secretions does not require suctioning for visualization. B: Same airway as in Fig. 34.1 after surgical removal of cyst. Glottic opening is visible just beneath epiglottis. Gentle tracheal pressure or decreasing neck extension while lifting tip of laryngoscope blade will improve visibility.

- Make certain all attachments are secure.
    - Avoid obscuring the point of connection of tube and adapter with any fixation device.
    - Secure tube carefully in position to avoid dislodgement, kinking, or movement.
        - Vary contact point from side to side to prevent damage to developing palate and palatal ridges (7,8,9 and 10).
        - Note relationship of head position to intratracheal depth of tube on radiograph (11,12).
- Do not leave endotracheal tube unattached from continuous positive airway pressure; the natural expiratory resistance is lost by bypassing the upper airway.
- Recognize that in neonates, endotracheal tubes are often pushed in too far because of the short distance from the glottis to the carina. Use a standardized graph or location device (2,5).
- Recognize the association of short trachea (fewer than 15 tracheal cartilage rings) with certain syndromes: DiGeorge syndrome, skeletal dysplasias, brevicollis, congenital rubella syndrome, interrupted aortic arch, and other congenital syndromes involving the tracheal area (13).
- Identify and prevent the factors that are most likely to contribute to spontaneous extubation (14).
    - Increased secretions
        - Necessitating more frequent suctioning
        - Loosening of tape
    - Infant activity
    - Procedures requiring repositioning infant
    - Tube slippage

E. Technique (See also Endotracheal Intubation on the Procedures DVD, and Appendix D for Techniques of Intubation Specific to Unique Patient Needs)

Orotracheal Intubation (Table 34.2)

- Position infant with the head in midline and the neck slightly extended, pulling chin into a â€œsniffâ€□ position (Fig. 34.4). The head of the infant should be at operator's eye level.

  It may be helpful to place a roll under the baby's shoulders to maintain slight extension of the neck.

- Put on gloves.
- Clear oropharynx with gentle suctioning.
- Empty stomach.
- Bag-and-mask ventilate and preoxygenate infant as indicated by clinical condition. Follow heart rate and oxygenation.

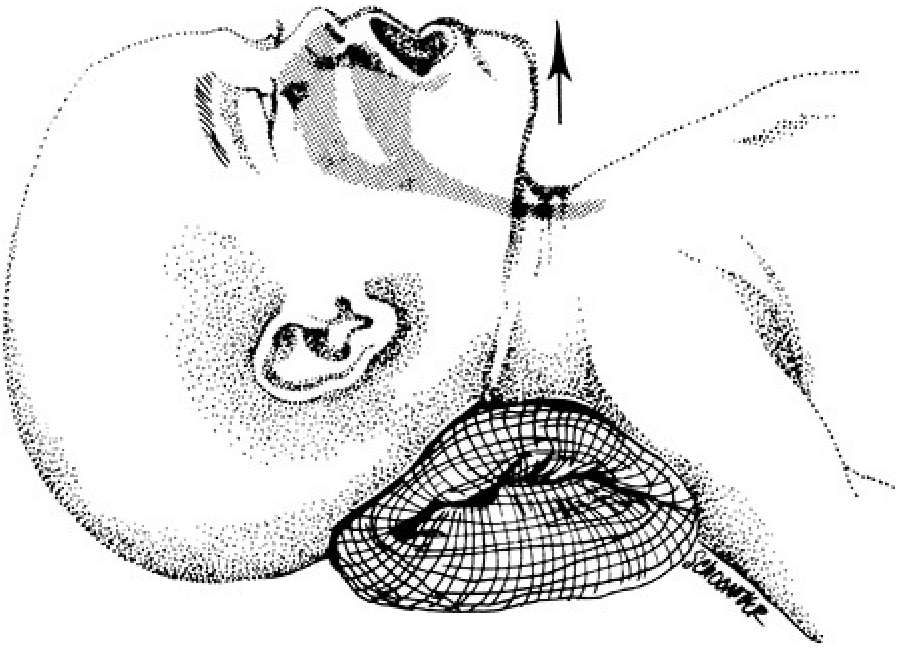

FIG. 34.4. Appropriate sniff position for intubation. Note that the neck is not hyperextended; the roll provides stabilizing support.

- Turn on the laryngoscope light, and hold the laryngoscope in left hand with thumb and first three fingers, with the blade directed toward patient.
  - Put thumb over flat end of laryngoscope handle.
  - Stabilize the infant's head with right hand.

    The laryngoscope is designed to be held in the left hand, by both right- and left-handed individuals. If held in the right hand, the closed, curved part of the blade may block the view of the glottis as well as make insertion of the endotracheal tube impossible.

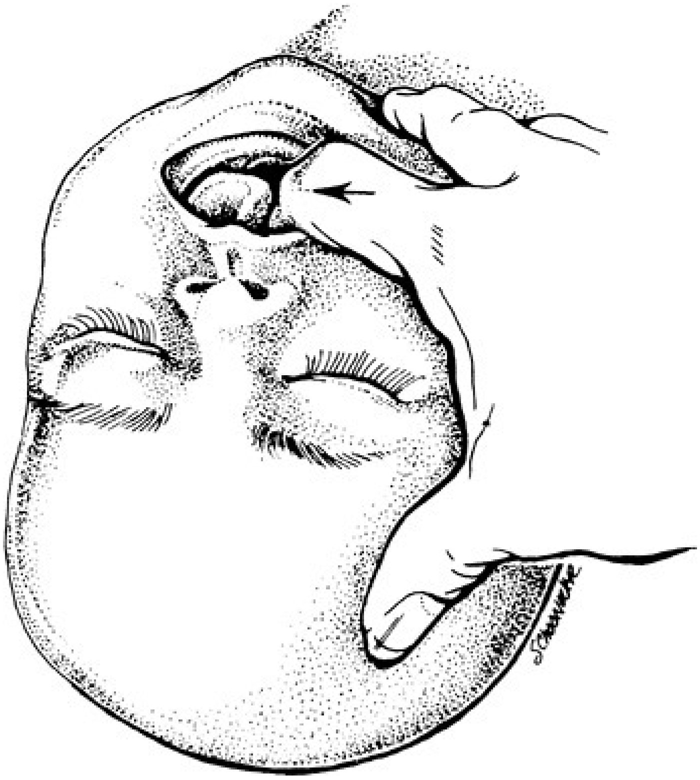

FIG. 34.5. Open the mouth and push the tongue aside with the forefinger while stabilizing the head with the thumb and other fingers of the right hand.

- Open infant's mouth and depress tongue toward the left with the back of right forefinger (Fig. 34.5).
    - Continue to steady head with rest of right hand.
    - Do not use the laryngoscope blade to open mouth.
- Under direct visualization, insert laryngoscope blade, sliding over the tongue until the tip of the blade is resting in the vallecula (the area between the base of the tongue and the epiglottis) (Fig. 34.6).

  In general, the blade tip should be placed in the vallecula. However, in extremely premature infants, the vallecula may be too small, in which case it may be necessary to use the blade tip to gently lift the epiglottis.

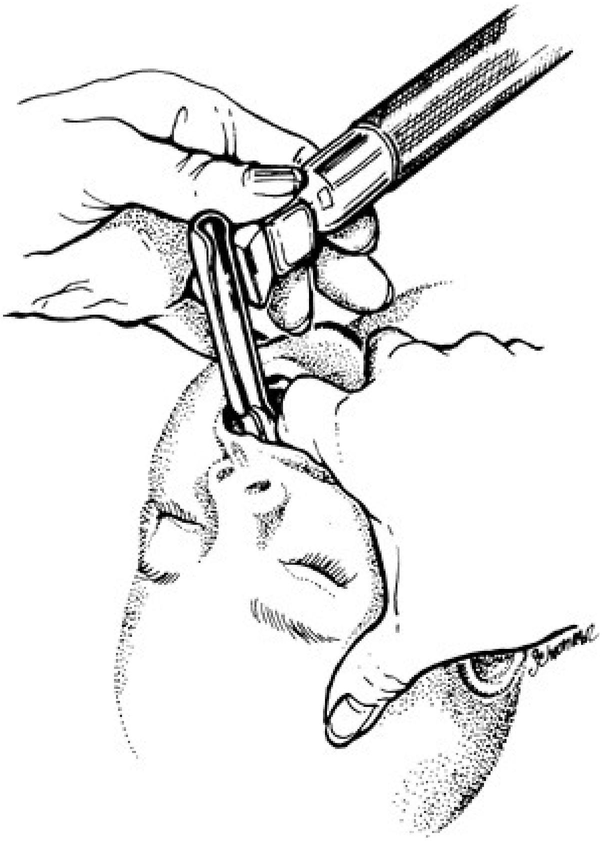

FIG. 34.6. Pass the laryngoscope carefully along the finger to the back of the oropharynx.

- Lift the laryngoscope blade to open mouth further and simultaneously tilt the blade tip slightly to elevate the epiglottis and visualize the glottis (Fig. 34.7).

  When lifting the blade, raise the entire blade in the direction that the handle is pointing. Do not lift the tip of the blade by using the upper gum line as the fulcrum for a rocking motion; this will not produce a clear view of the glottis and will place excessive pressure on the alveolar ridge, potentially impeding future tooth formation.

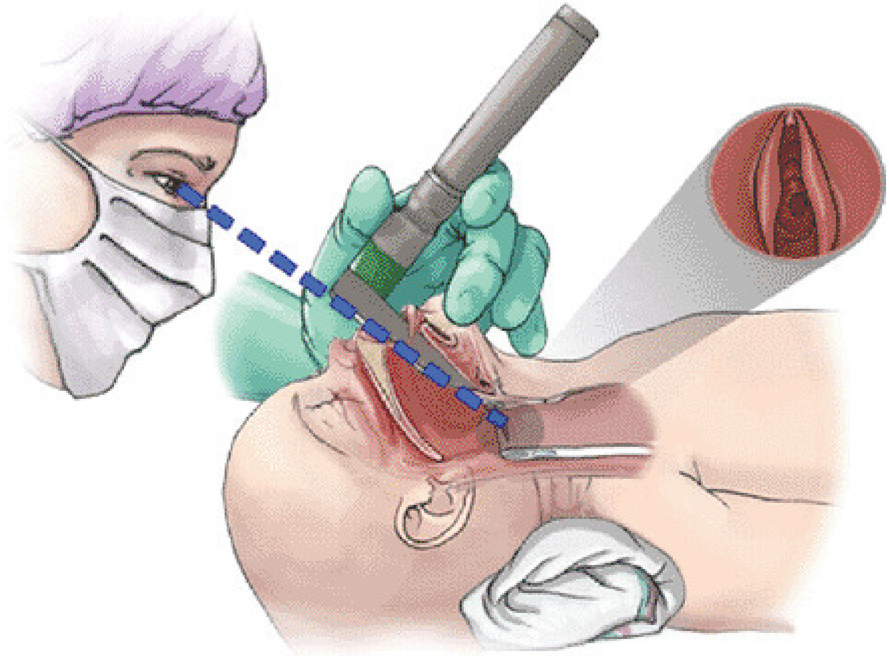

FIG. 34.7. With the laryngoscope at the proper depth, tilt the blade with the tongue as the fulcrum; at the same time, pull on the laryngoscope handle to move the tongue without extending the infant's neck. Use more traction than leverage.

- Suction as necessary.
- Have an assistant apply gentle pressure at the suprasternal notch to open the larynx and to feel the tube pass (15).
- Hold tube in right hand with concave curve anterior, and pass it down the right side of the mouth, outside the blade, while maintaining direct visualization (Fig. 34.8).

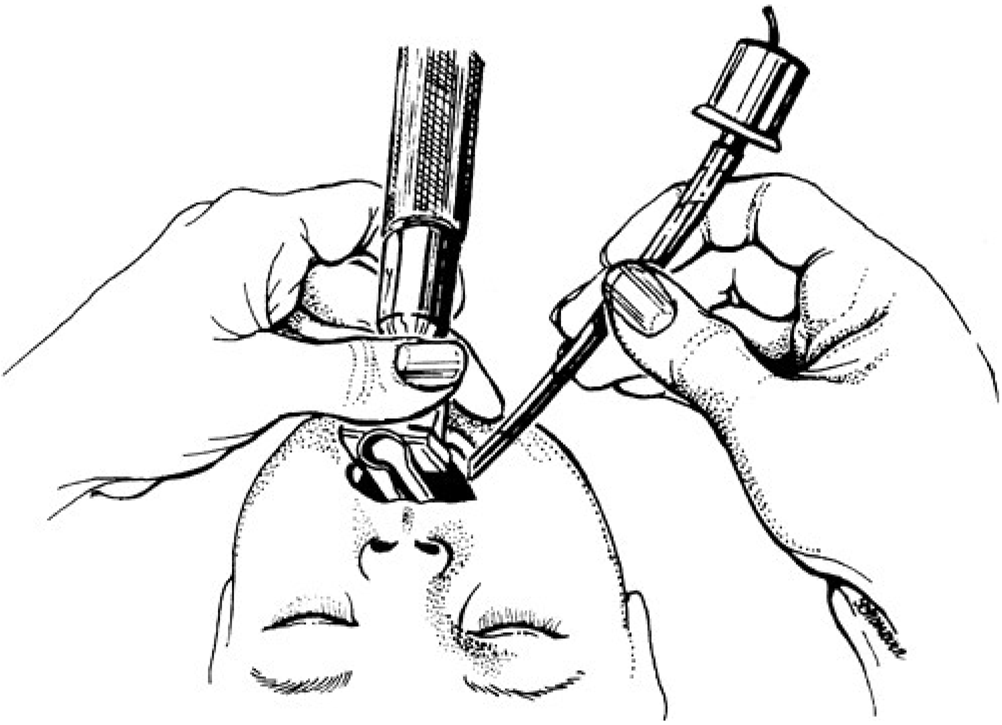

FIG. 34.8. Visualize the glottis and pass the endotracheal tube into the oropharynx. Keep the tube outside the curve of the laryngoscope blade for better mobility.

- Once the vocal cords and trachea are visualized, insert the endotracheal tube through vocal cords, approximately 2 cm into trachea or until the tip is felt passing the suprasternal notch by the assistant (Fig. 34.9).
- If the tube appears too large or does not pass easily, decrease angle of neck extension.
- Confirm endotracheal tube position within the trachea (16,17).
    - We currently use Pedi-Cap (Nellcore, Waukesha, WI) end-tidal CO_2 detector to verify the position of the endotracheal tube within the trachea. This technique responds quickly to exhaled CO_2 with a simple color change from purple to yellow. It also features an easy-to-see display window that provides constant visual feedback with breath-to-breath response (Fig. 34.10).
    - While gently ventilating with an Ambu bag, auscultate to make sure the breath sounds and chest movement are equal in both sides of the chest.
    - Observe respiratory wave pattern on oscilloscope to determine that artificial breath is at least as effective as spontaneous breath.
    - Verify lip-to-tip distance.

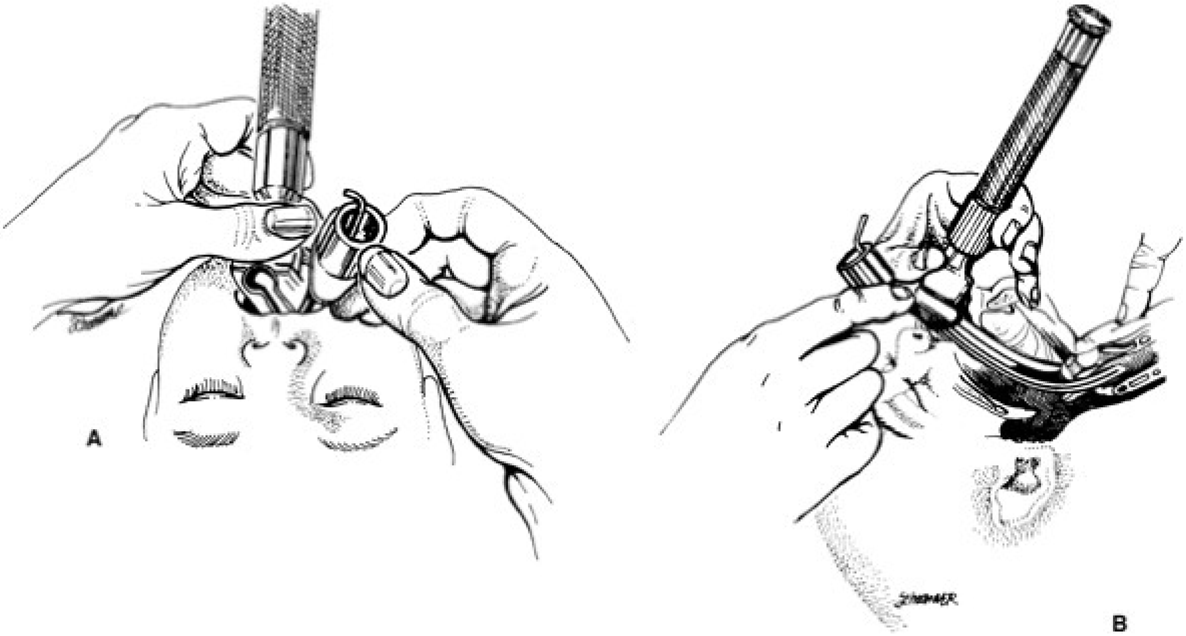

FIG. 34.9. A: Pass the endotracheal tube through the glottis to the appropriately predetermined length and remove laryngoscope. B: An assistant applies gentle pressure in the suprasternal notch to open the larynx and to detect when the tube passes into the trachea.

- If the endotracheal tube is correctly placed in the midtracheal region, there should be
    - Pedi-Cap response to exhaled CO_2 by a reversible color change, purple to yellow
    - Equal bilateral breath sounds
    - Slight rise of the chest with each ventilation

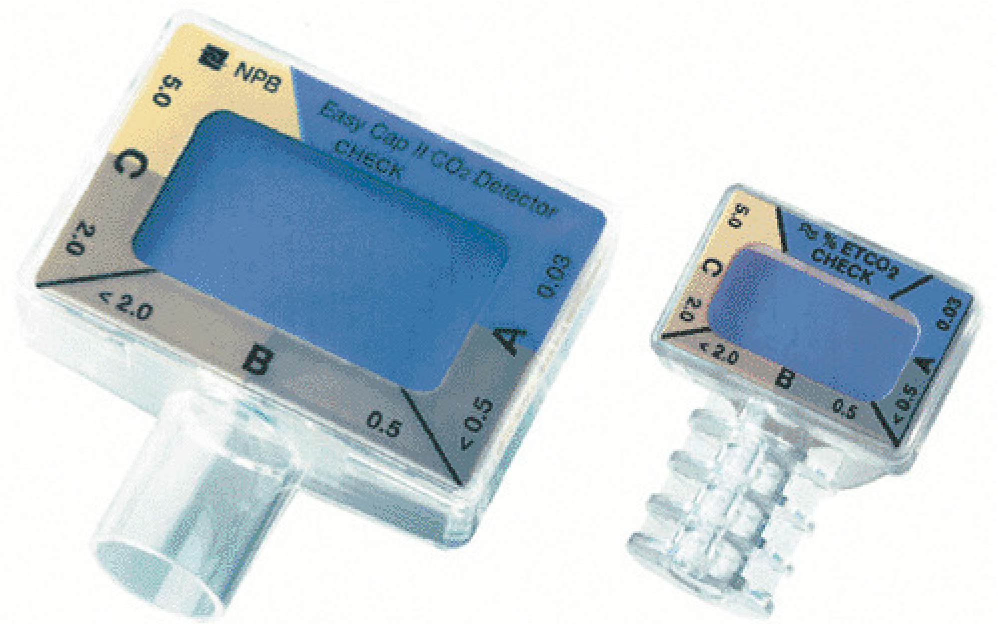

FIG. 34.10. Pedi-Cap CO_2 detector. Pedi-Cap is a trademark of Tyco Healthcare Group LP. (Reprinted by permission from Nellcor Puritan Bennett, Inc).

  - No air heard entering stomach
  - No gastric distention
- Suction endotracheal tube with sterile catheter, following technique described under F.
- Attach appropriate mechanical ventilatory device.
- Adjust required F_iO_2.
- Secure the tube to the infant's face (Figs. 34.11 and 34.12).

  When using adhesive tape, make sure that the face is dried thoroughly to ensure adherence of the tape and to protect the skin. A more permanent fastening can be done later when a radiograph confirms correct placement of the endotracheal tube (18).

- Obtain chest radiograph with head in neutral position, and note the lip-to-tip distance and direction of bevel (Figs. 34.13 and 34.14).

  When a correct tube length has been determined for the infant, note the tube marking at the level of the infant's lips.

- Cut off excess tube length to leave 4 cm from the infant's lips and reattach adapter firmly.

  If a longer external length is required, before replacing the adapter, slip a short length of a larger endotracheal tube around the narrower tube to prevent kinking, for example, a 6-cm length of 3.5-mm tube over a 2.5-mm tube.

- Reconfirm tube marking at lip regularly, to avoid unnoticed advancement of the tube into the airway.
- Retape tube as necessary to maintain stability.

Nasotracheal Intubation

In neonates, orotracheal intubation is preferred because it is easier and faster to perform and there are few proven advantages to nasal intubations in small infants (19,20). Nasotracheal tubes are preferred in very active infants with copious oral secretions, making it difficult to keep the tube taped in position. When anatomy precludes oral intubation or for oral surgery, nasotracheal intubation may become necessary. Premedication with succinylcholine/atropine or morphine/atropine has been reported to allow a shorter time for intubation, with fewer negative systemic effects (21).

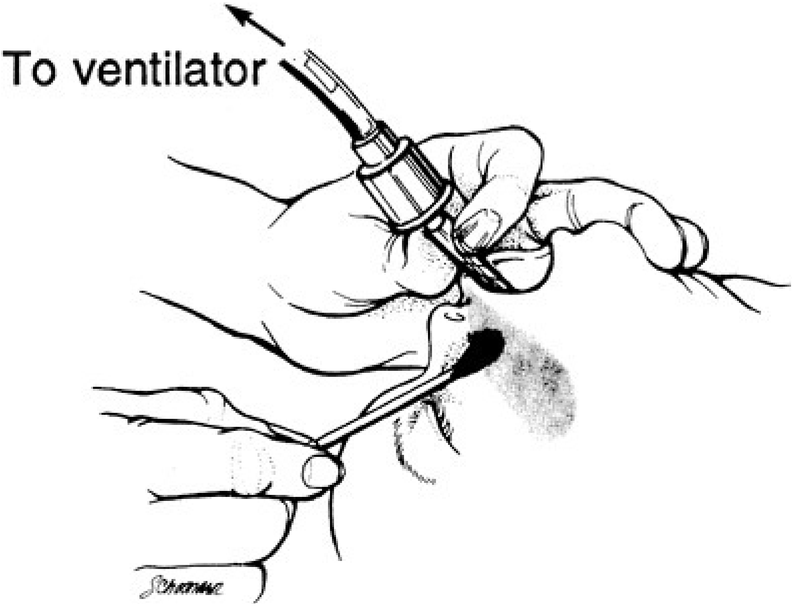

FIG. 34.11. After initially determining that the endotracheal tube is in the correct position, connect the tube to an artificial ventilation source. In the term neonate begin fixation of the tube by painting the philtrum with tincture of benzoin and allowing it to dry. Avoid use of tincture of benzoin in low-birthweight infants; it increases epidermal stripping.

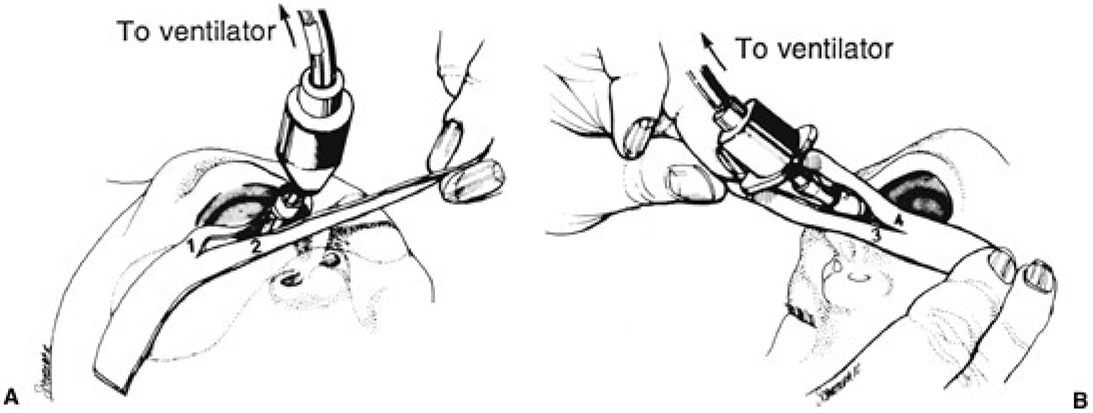

FIG. 34.12. Fixation of tube with half split tape. A: First half of one split tape (1) encircles the tube, and the other half (2) attaches to the upper lip. B: Second split half (3) attaches to the upper lip, while the bottom half (4) encircles the tube.

- Use sterile endotracheal tube. If stylet is used to curve tube, remove it prior to nasal insertion.

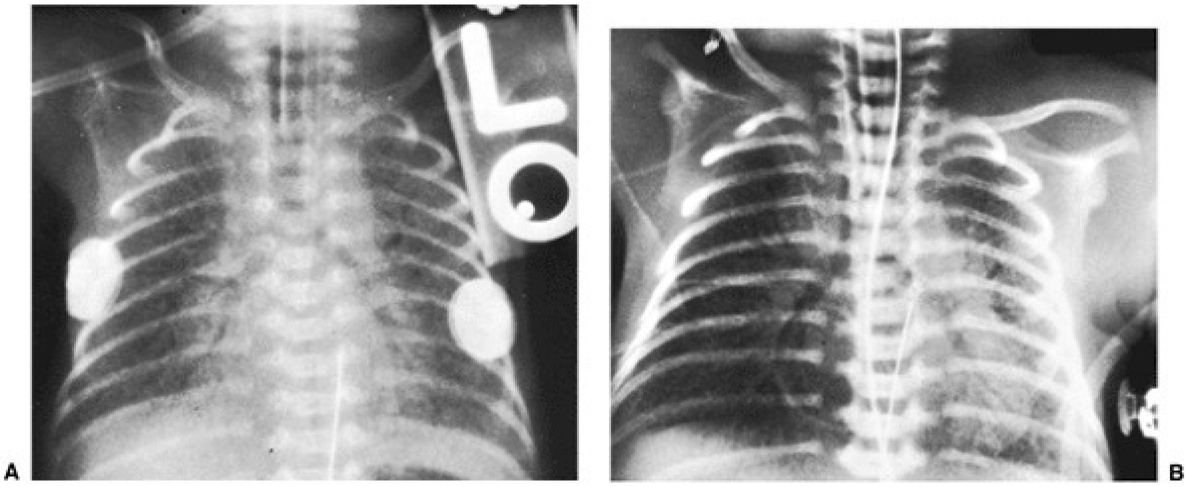

FIG. 34.13. Although the carina is usually at the level of T4 on the anteroposterior supine chest radiograph, this relationship may be significantly disturbed by a number of factors, including radiographic technique (x-ray tube position, angulation). For this reason and because the carina is usually easily visualized, as in these cases, one should directly relate the tip of the endotracheal tube to the carina radiographically, knowing the position of the head at the time of film exposure. In both cases, films were taken to verify endotracheal tube position but demonstrated problems with other procedures. A: Appropriate radiographic angle. (Note the oral gastric tube in the esophagus and not reaching the stomach.) B: Slightly lordotic radiographic angle. (Note the central venous line coiled in the heart.)

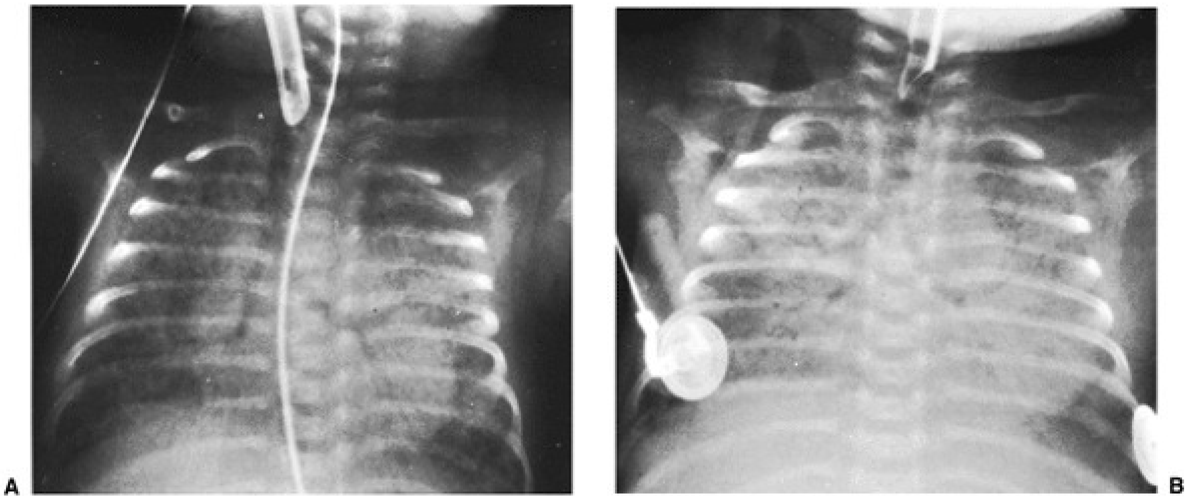

FIG. 34.14. Sequential radiographs demonstrate the effect of head rotation on bevel direction. A: With the head rotated to the right, the bevel appears to be directed against the tracheal wall. B: The head is rotated to the left, and the bevel is now positioned properly. If the bevel is directed against the posterior tracheal wall in a spontaneously breathing infant, there may be symptoms of tracheal obstruction on expiration. Rather than turning the head to achieve satisfactory position, rotate the endotracheal tube and retape in position.

- If desired, premedicate with atropine (20 mcg/kg) and succinylcholine (2 mg/kg) just before inserting tube. Be prepared to provide assisted bag-and-mask ventilation.
- If orotracheal tube is already in place, release fixation and position at far left of the mouth, to allow continued ventilation during nasotracheal intubation.
- Directly visualize oropharynx with laryngoscope as described previously, taking particular care not to hyper-extend neck.
- Suction oropharynx while keeping laryngoscope in place.
- Insert tube through nostril following natural curve of nasopharynx.

- As tube passes into the pharynx, align the tip with the center of the tracheal orifice, moving infant's head as needed.
- When the tip of the nasotracheal tube appears to be in direct line with the glottis, have assistant carefully withdraw the orotracheal tube.
- Apply gentle pressure over the suprasternal notch and advance tube through cords.

  Use of the Magill forceps is often more cumbersome than helpful in smaller infants. A Magill forceps should always be available, but in a properly positioned infant, a curved tube usually passes directly into the trachea without forceps unless the neck is excessively extended, flexed, or rotated. Secure tube and verify position. The length of a nasotracheal tube for correct positioning of the tip in the trachea is approximately 2 cm longer than the equivalent length of an orotracheal tube.

F. Tracheal Suctioning

Suctioning of the nose, mouth, and pharynx is potentially quite traumatic in neonates. The same equipment, precaution, and complications apply as for tracheal suctioning. Always suction an endotracheal tube before suctioning the mouth; suction the mouth before the nose.

- Indications
  - To clear tracheobronchial airway of secretions
  - To keep artificial airway patent
  - To obtain material for analysis or culture
- Relative contraindications
  - Recent surgery in the area
  - Extreme reactive bradycardia
  - Pulmonary hemorrhage
  - Oscillatory ventilation

- Equipment

Sterile

- Saline for instillation into airway
- Saline or water for irrigation of catheter
- Gloves
- Suction catheters
  - Available safety features
    - Markings at measured intervals
    - Microscopically smooth surface
    - Multiple side holes in different planes
    - Large-bore hole for occlusion to initiate vacuum
    - No more than half the inside diameter of artificial airway
      - Use 8 Fr for endotracheal tube >3.5 mm.
      - Use 5 Fr for endotracheal tube <3.5 mm.
- Modified endotracheal tube adapter that allows passage of suction catheter without disconnecting tube from ventilator (Novometrix C/S Suction Adapter; Novometrix Medical Systems, Wallingford, CT, USA) (22)

- Vacuum source
    - Pressure set just high enough to move secretions into suction catheter
    - Mechanically controlled pressure source Pressure generated by oral suction on mucus extractors can be extremely variable and dangerously high (23).

Nonsterile

- Adjustable vacuum source with specimen trap, tubing, and pressure gauge
- Ventilatory device as indicated
    - Manometer
    - Warmed, humidified oxygen at controlled level
    - Bag with positive end-expiratory pressure device

- Precautions
    - When feasible, use two people when suctioning airway, to minimize risk of patient compromise and complications and to shorten time for procedure.
    - Determine for each patient if it is better to continue mechanical ventilation during suctioning or to use a sigh with inflation hold after suctioning. Consider effect of interruption of ventilator therapy and loss of lung volume with each catheter passage.
    - Allow patient to recover between passages of catheter.
    - Stabilize head and airway to prevent tube dislodgement.
    - Assess secretions by auscultation and palpation to determine frequency for suctioning.
        - Avoid unnecessary suctioning just to follow a schedule.
        - Schedule prophylactic suctioning for tube patency only as often as needed to maintain it.
        - Consider increase in monitored airway resistance as indication for suctioning (24).
    - Readjust humidification as indicated by catheter and volume of secretions.
    - Avoid inadvertent suction during insertion of catheter.

      Use lowest vacuum pressure effective in clearing secretions within a few seconds.

    - Do not insert catheter as far as it will go or until reflex cough occurs. Use prescribed length. Do not suction if catheter is inserted too far; just touching the catheter to the tracheal wall may cause trauma.
    - Limit time of insertion and suctioning to least time required to remove secretions.
- Technique for intubated patients
    - For artificial airways, use sterile technique with one sterile gloved hand and one free hand.
    - Monitor oxygen saturation continuously during suctioning.
    - Monitor heart rate continuously.
    - It is usually best to remove infant from ventilator and have second person perform assisted ventilation manually, using following guidelines adjusted to individual needs:
        - F_iO_2 set at or up to 10% higher than baseline
            - Monitor oxygenation. Adjust F_iO_2 to prevent swings in oxygenation.
            - Evaluate effect of procedure.
        - Peak inspiratory pressure as on ventilator or up to 10 cm H_2O higher
        - Continuous distending airway pressures same as on ventilator
        - Respiratory rate 40 to 60 breaths/min, applying an inspiratory hold intermittently

          When there is a high risk of pulmonary air leak as in the presence of significant interstitial emphysema, it may be safer to use a technique of rapid manual ventilation at lower peak pressure instead of sighing with a prolonged inspiratory pressure. In other cases in which loss of lung volume with suctioning is of greater concern, use sigh with a hold on inflation at a rate similar to ventilator. With suctioning, there is a loss of lung volume with a decrease in compliance. The adverse effect persists for a significant time when mechanical ventilation at the same setting is used during and after the suction procedure.

- Determine length of endotracheal tube plus adapter and note on suction catheter as limit of depth of insertion.
- Set vacuum at lowest level to achieve removal of secretions. The level of vacuum required depends on a number of variables, including
    - Air tightness of system and fluctuations in generated vacuum pressure
    - Accuracy of manometer
    - Diameter of catheter (smaller catheter, higher pressure)
    - Thickness and tenacity of secretions
- Holding catheter in one hand, moisten tip with water or saline. Note appropriateness of suction level by rate of liquid uptake. Adjust pressure with free hand.
- Open artificial airway with free hand.
    - Detach from bag; hold oxygen near end of tube, or
    - Open suction port of specialized endotracheal tube adapter.
- With free hand, stabilize airway. Pass catheter down airway to depth limit noted for the patient's endotracheal tube. Do not apply vacuum during insertion (i.e., keep suction control port open).
- Close proximal suction control port and withdraw catheter.
- Limit time for insertion and removal to 15 to 20 seconds.
- Reattach endotracheal tube to bag and ventilate for 10 to 15 breaths or until patient is stable.
    - Note oxygenation.
    - Note heart rate.
    - Note chest excursions.
- If secretions are thick or tenacious, instill 0.25 mL of saline into endotracheal tube and continue ventilation.
- Clear catheter with sterile water.
- Repeat process until airway is clear.

G. Fixation Techniques

Many fixation devices and techniques have been described in the literature. None of them can prevent all accidental extubations or malpositions (18,25,26 and 27). Here, we describe a simple and effective method.

- Prepare two 8- to 10-cm lengths of adhesive tape split half of the length and one 10- to 15-cm length without a split.
- Paint skin adjacent to the sides of the mouth and above the lips with tincture of benzoin (Fig. 34.11).
- Allow to dry while holding the tube in place.
- Tape the unsplit end of the adhesive to the cheek on one side of the mouth, and wrap the bottom half clockwise around the endotracheal tube just at the lip. Fold the last 2-mm end of tape on itself to leave a tab for easier removal (Fig. 34.12).
- Secure the other half above the upper lip.
- Repeat the procedure from the other side, reversing the direction of the taping and securing half on that side of the upper lip (Fig. 34.12).
- Secure one end of the long tape to one cheek at the zygoma. Loop the tape around the tube, and secure the other end to a similar point on the opposite cheek.
- Note the markings on the endotracheal tube at the level of the lips and the tape.
- Whenever the tape seems to be loosened from secretions, remove tape and repeat application of benzoin while holding tube at proper lip-to-tip depth.

H. Planned Extubation

Various vasoconstrictors and anti-inflammatory medications have been recommended to reduce postextubation stridor and to improve the success of extubation. Systemically administered dexamethasone appears to have very little if any effect in reducing acute postextubation stridor in neonates and children (28,29). Local application of steroids directly to the vocal cords has not been well studied.

- Perform chest physiotherapy and suction prior to extubation.
- Release all fixation devices while holding tube in place.
- Using manual ventilation, give infant a sigh breath, and withdraw tube during exhalation.
- Avoid suctioning during tube withdrawal, unless specifically removing foreign material from trachea.
- Allow recovery time before suctioning oropharynx.
- Keep the inspired gases well humidified.

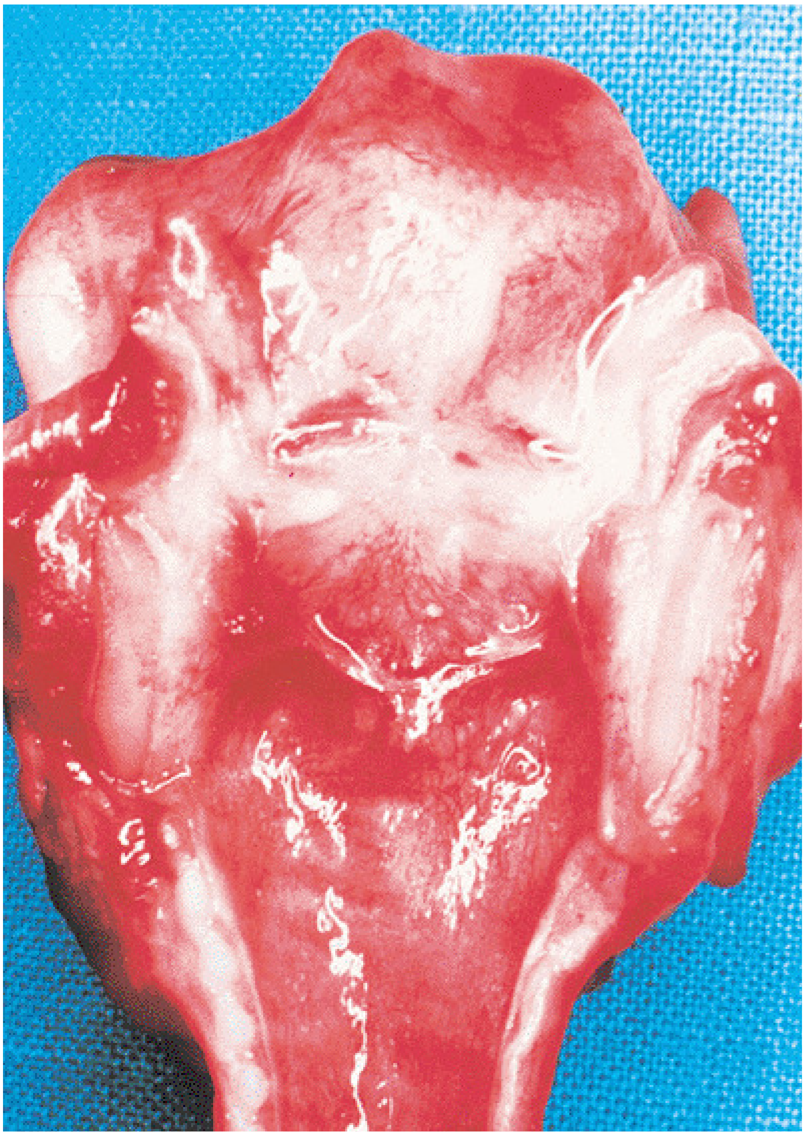

FIG. 34.15. Subglottic erosion and stenosis after intubation.

I. Complications

- Acute trauma (30,31,32 and 33)
    - Tracheal or hypopharyngeal perforation
    - Pseudo-diverticulum
    - Hemorrhage
    - Laryngeal edema
    - Mucosal necrosis (Fig. 34.15)
    - Vocal cord injuries
    - Dislocation of arytenoid
- Chronic trauma (31,32,33,34,35,36,37, and 38)
    - Cricoid ulceration and fibrosis
    - Glottic and/or subglottic stenosis (Fig. 34.15)
    - Subglottic granuloma (Figs. 34.16 and 34.17)
    - Hoarseness, stridor, wheezing
    - Subglottic cyst
    - Tracheomegaly
    - Protrusion of laryngeal ventricle
- Interference by oral tube with oral development (7,8,9 and 10,39,40,41,42, and 43)
    - Alveolar grooving
    - Palatal grooves (Fig. 34.18)
    - Acquired oral commissure defect (Fig 34.19)

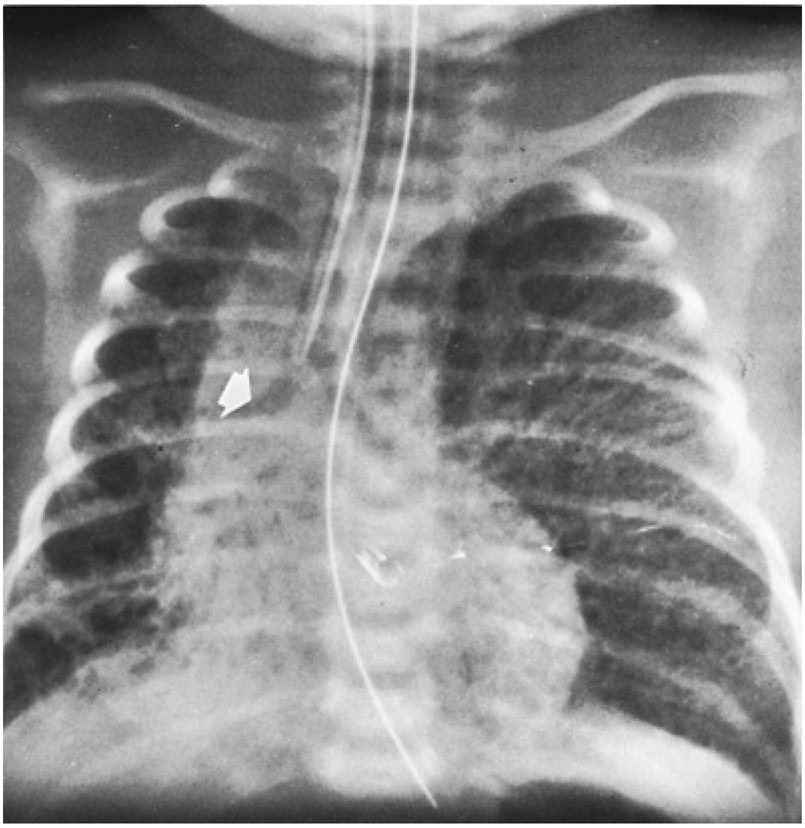

FIG. 34.16. Radiographic magnification high-kilovoltage film (2 x) demonstrating an abrupt cutoff of the right bronchus intermedius (arrow) due to an endobronchial granuloma with secondary volume loss at the right lung base. Although these granulomas may be due to endotracheal tube trauma, in this area they are more likely related to suction tube injury. The endotracheal tube is just entering the right bronchus.

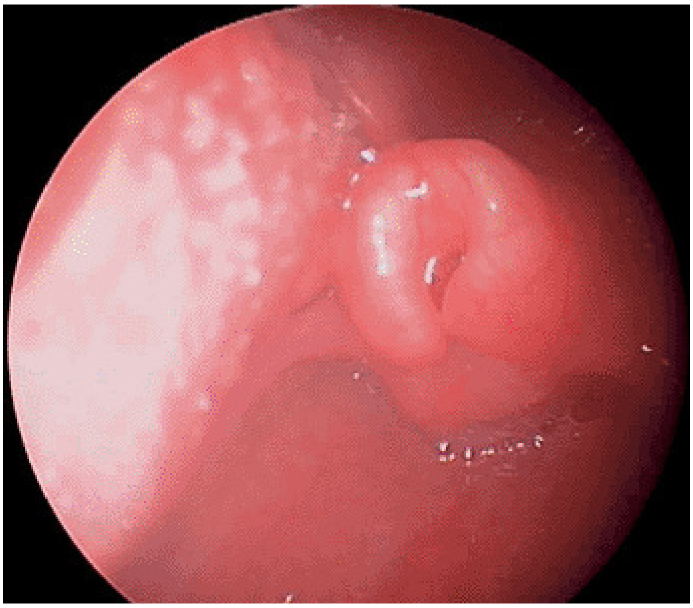

FIG. 34.17. Glottic granuloma after intubation. Epiglottis is manually retracted to reveal granuloma below cords. Esophageal opening is clearly visible beneath airway.

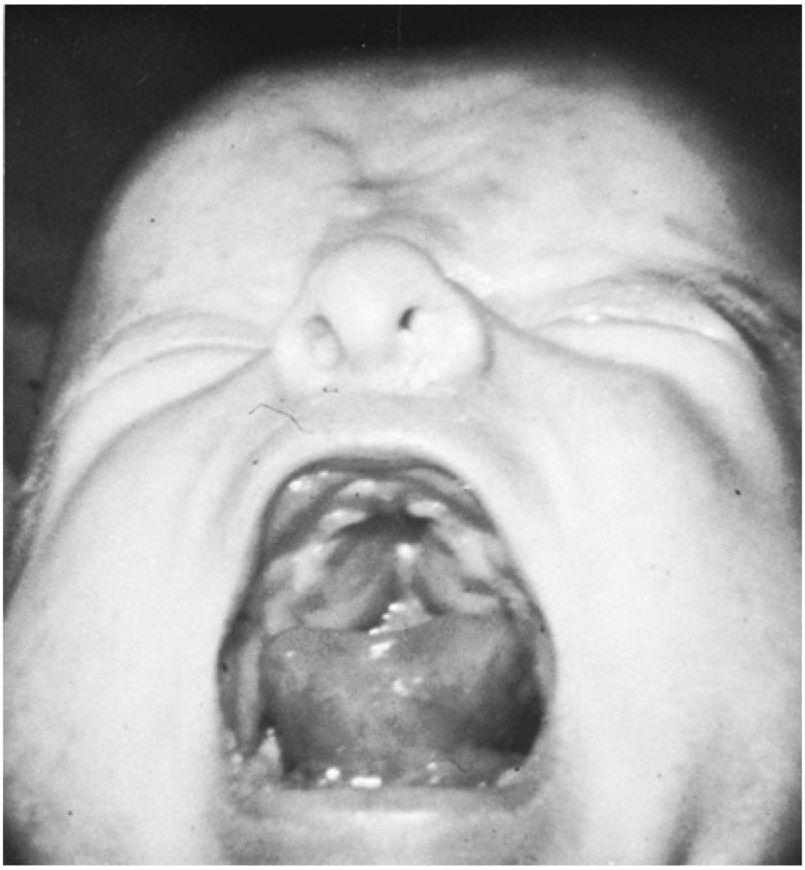

FIG. 34.18. Palatal groove after prolonged oral intubation. Such grooves may be seen after prolonged use of endotracheal or oral gastric tubes when the normal forces of the tongue are prevented from assisting palatal development.

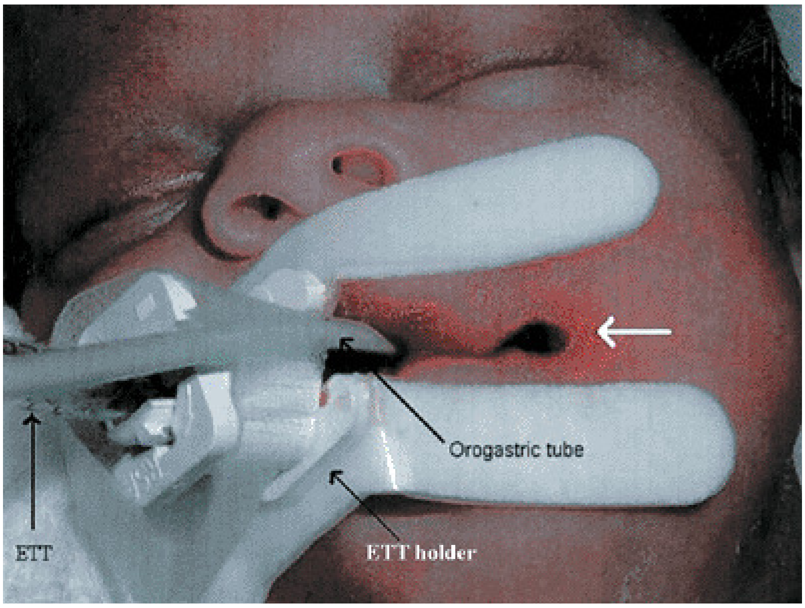

FIG. 34.19. Acquired oral commissure defect: a complication of prolonged endotracheal intubation. (Reprinted by permission from Macmillan Publishers Ltd. Journal of Perinatology. 2005;25:612.)

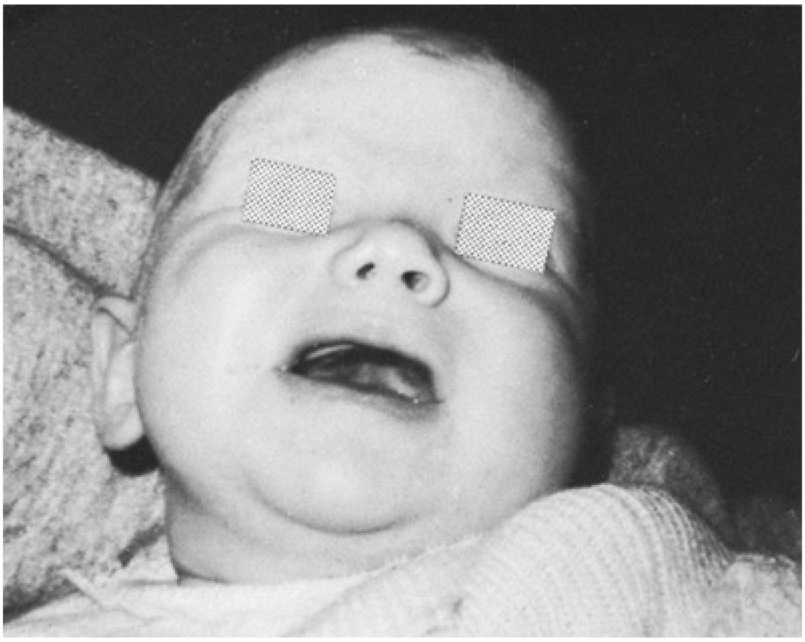

FIG. 34.20. Nasal stenosis due to nasal cartilage necrosis following an indwelling nasotracheal tube.

  - Posterior cross-bite
  - Defective dentition
    - Enamel hypoplasia
    - Incisor hypoplasia
  - Poor speech intelligibility
- Local effects from nasal tube (44,45 and 46)
  - Erosion of nasal septum
  - Stenosis of nasal vestibule (Fig. 34.20)

  - Nasal congestion
  - Midfacial hypoplasia
  - Otitis media
- Systemic side effects (47,48,49,50 and 51)
  - Infection
  - Aspiration
  - Increased intracranial pressure
  - Hypoxemia
  - Hypertension
  - Apnea
  - Bradycardia and cardiac arrest
- Misplacements into esophagus or bronchus (52,53) (Figs. 34.21, 34.22 and 34.23)
  - Atelectasis
  - Pulmonary air leak
  - Loss of tube into esophagus
  - Across tracheoesophageal fistula
- Displacement; accidental extubation (54)
- Obstruction (54)
- Kinking, proximally or distally
- Unrecognized disconnection from adapter or pressure source

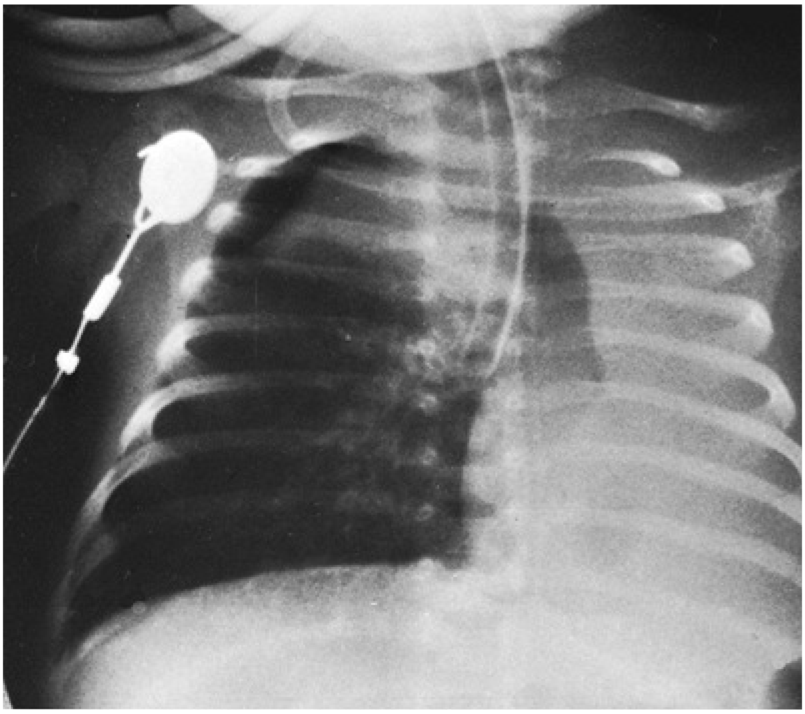

FIG. 34.21. Radiograph demonstrating an endotracheal tube malpositioned in the bronchus intermedius, with resulting atelectasis of the right upper lobe and of the left lung. There is marked overaeration of the right middle and lower lobes but no pneumothorax as yet.

- Rupture of endotracheal tube (55)
- Foreign body from stylet left unrecognized in airway
- Swallowed laryngoscope light (56)
- Postextubation atelectasis (54)
- Increased airway resistance increasing work of breathing (57,58)

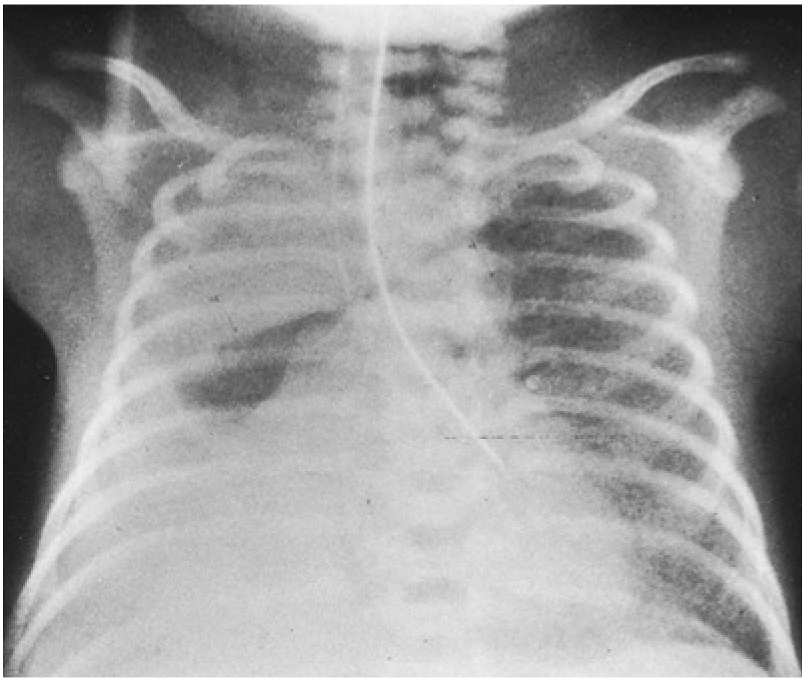

FIG. 34.22. Relatively uncommon malposition of an endotracheal tube in the left bronchus with atelectasis of much of the right lung.

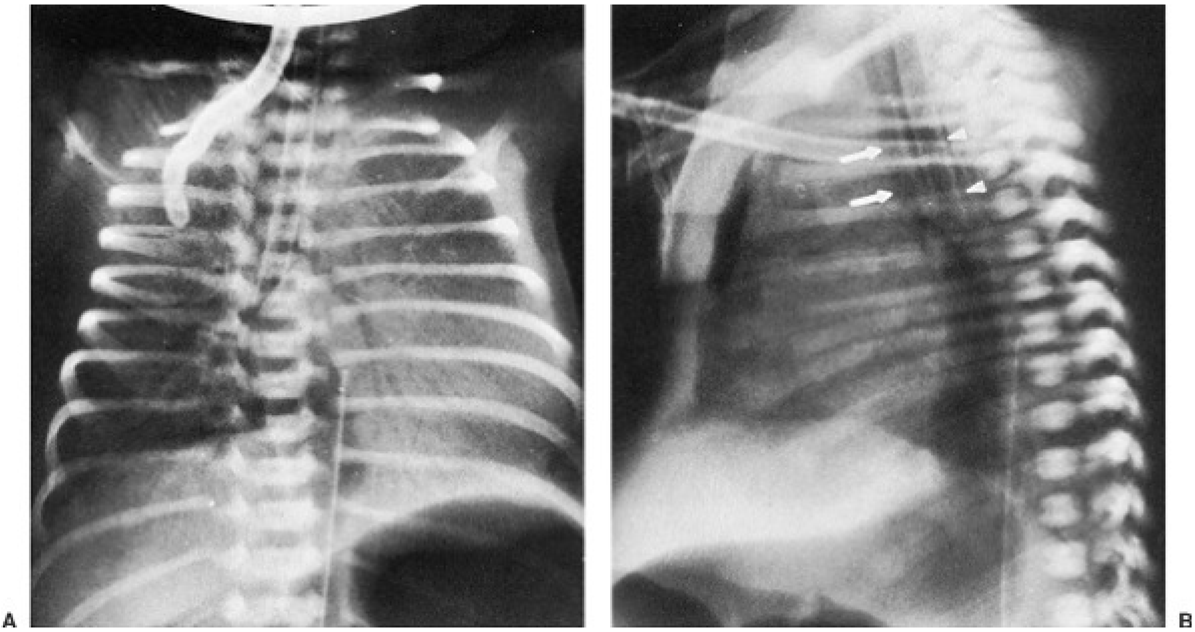

FIG. 34.23. A: Radiograph suggesting that the endotracheal tube is in the right mainstem bronchus. Note the gaseous distension of the stomach and intestine. The wavy tube on the right is external. B: In the lateral view, the same endotracheal tube is easily seen to be in the esophagus (arrowheads) posterior to the trachea (arrows).

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35-Tracheotomy

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Gregory J. Milmoe

A. Indications

- Prolonged need for ventilator support â€”most common
- Acquired subglottic stenosis after prolonged intubation
- Craniofacial abnormalities with severe airway obstruction, e.g., Pierre-Robin sequence, Pfeiffer syndrome, Treacher Collins syndrome
- Congenital bilateral vocal cord paralysis
- Laryngeal web, subglottic hemangioma
- Congenital tracheal stenosis, severe tracheomalacia
- Congenital neuromuscular disease with insufficient respiratory effort
- Neurologic disease with aspiration risk, central apnea, or intractable seizures

B. Contraindications

- Unstable physiology wait until stabilized
    - Sepsis
    - Pneumonia not yet controlled
    - Pulmonary instability requiring high inspiratory pressures (PIP >35-40) or need for high-frequency ventilation
    - Cardiovascular instability, e.g., shunting, arrhythmia, or hypotension
    - Evolving renal or neurologic injuries
- Distal obstruction not relieved by tracheostomy
    - Congenital stenosis at the carina
    - External compression from mediastinal mass
- Congenital anomalies that make the trachea relatively inaccessible
    - Massive cervical hemangioma bleeding issues
    - Massive cervical lymphangioma severe distortion of neck anatomy
    - Massive goiter might be manageable medically
    - Chest syndromes with severe kyphoscoliosis or tracheal distortion

C. Precautions

- Patient should be stable (see Contraindications); anticipate need for increased pulmonary support temporarily to counter atelectasis and reactive secretions from surgical stimulation.

- Tracheotomy tubes allow for air leak through stoma and through larynx. In contrast, an endotracheal tube fits more snugly at the cricoid, creating a more closed system for ventilation.
- Neonates are less able to tolerate bacteremia, so use perioperative antibiotic to cover skin flora.
- If the patient is not currently intubated, have endoscopy equipment available and discuss intubation options with the anesthesiologist.
- The infant larynx differs from that of the adult and older child (Fig. 35.1).
    - More pliable and mobile
    - Relatively higher in neck
    - Thymus and innominate artery can override trachea in surgical field
- This procedure should be done only in a facility where there is appropriate support for postoperative management.

D. Equipment

- Prep tray with brushes, towels, and betadine
- Tracheotomy tray
    - Scalpel with no. 15 blade
    - Hemostats
    - Small scissors (iris, tenotomy, small Mayo)
    - Retractors Senn or Ragnel
    - Suction no. 7 Frazier
    - Forceps Adson
- Sutures: 3-0 and 4-0 nonabsorbable on small, curved needles
- Neonatal tracheotomy tubes
    - Have several calibers available
    - Standard tubes are noncuffed, but in special circumstances a cuff may be needed.

E. Technique

- Check instruments, sutures. and available tracheotomy tubes.
- On patient arrival in operating room, apply monitors, check intravenous line, and confirm satisfactory ventilation through endotracheal tube.
- Anesthesia team proceeds with inhalation agents, oxygen supplementation, and intravenous agents as needed for satisfactory level of general anesthesia.
- Position patient with neck extended using shoulder roll.
- Remove nasogastric tube to avoid confusion when palpating trachea. Do not place esophageal stethescope either.
- Inject skin incision and the deeper tissues with local anesthetic (0.5 to 1.0 mL of Â½% lidocaine with 1:200,000 epinephrine).
- Prep the surgical site from above the chin to below the clavicles. Give IV antibiotic to cover skin flora.
- Drape the patient with surgical towels, allowing the anesthesiologist access to the endotracheal tube and the securing tape.
- Identify the following landmarks: suprasternal notch, chin, midline, trachea, and cricoid. In small neonates, the cricoid may be difficult to palpate.
- The skin incision is made roughly midway between the sternal notch and the cricoid, either vertically or horizontally. Both tend to heal as a circular stoma, but the horizontal has a slightly better cosmetic effect, while the vertical allows more exposure in the midline.
- Excess subcutaneous fat can be excised with cautery.
- Identify the strap muscles and repeatedly palpate the trachea to confirm the midline. Split the raphe to separate the muscles.

- Grab the fascia of the strap muscles with hemostats to retract them outward and laterally, thereby exposing the thyroid gland, cricoid, and trachea.
- Senn retractors can then be placed on either side of the trachea for better view.
- The thyroid gland can usually be displaced by blunt dissection to expose the tracheal rings. If not, then the isthmus is divided and suture ligated.
- Place vertical stay sutures in paramedian position at the level where tracheal entry is planned usually the third and fourth ring (Fig. 35.2).
- Incise trachea vertically for 2 or 3 rings, depending on the size needed for the tube employed.
- The anesthesiologist can then loosen the tape and withdraw the endotracheal tube until the tip is just visible (Fig. 35.3).
- The appropriate tracheostomy tube is then placed with the flange parallel to the trachea so that the tube more easily enters the trachea and passes posteriorly before rotating the flange 90 degrees back to its routine orientation.
- The anesthesiologist confirms placement by checking end-tidal carbon dioxide and oxygen saturation, as well as auscultation of both sides.

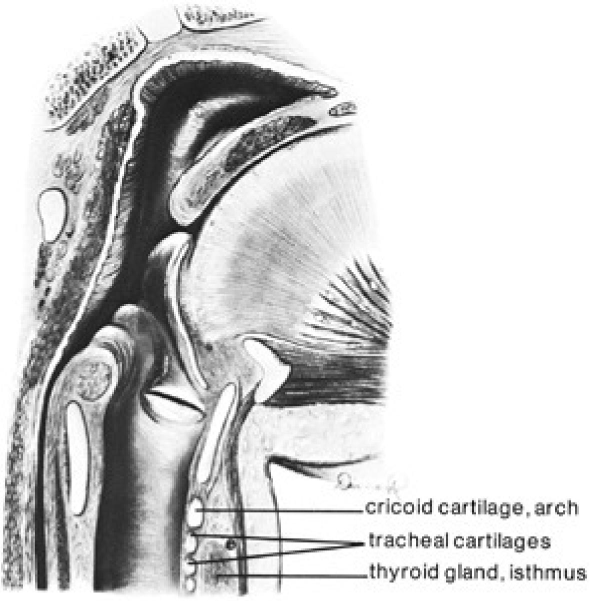

FIG. 35.1. Sagittal section. Larynx lies more cephalad than in adult. Note the proximity of the thyroid isthmus to the tracheal rings. (Drawing contributed by John Bosma, M.D.)

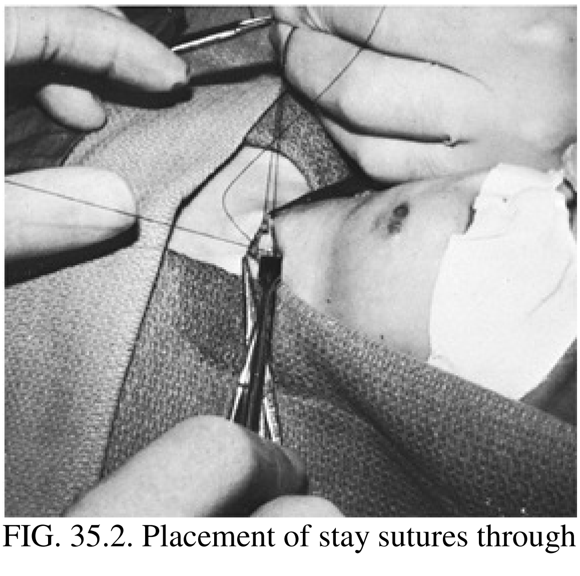

FIG. 35.2. Placement of stay sutures through the tracheal wall.

- The tracheostomy tube is then secured with twill tape tied around the neck firmly. Once tied, only one finger should fit between the tape and the neck when the baby's neck is in neutral position.
- The stay sutures are then secured to the chest with tape labeled as to correct side (Fig. 35.4).
- Transport the patient back to intensive care with a backup endotracheal tube and laryngoscope.
- Obtain chest radiograph on arrival in unit to check tube position and lung status.

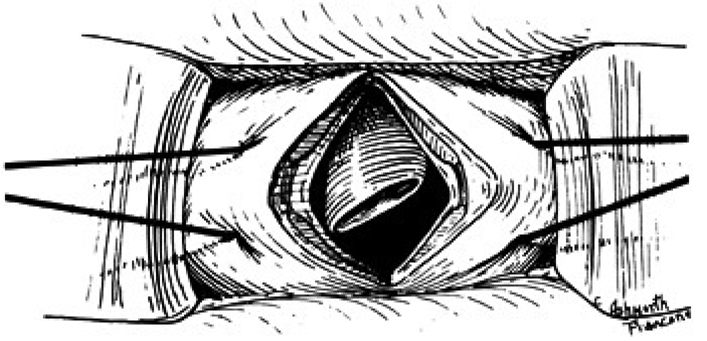

FIG. 35.3. Artistic conception of view through tracheal incision with the tip of the endotracheal tube visible. Stay sutures hold cartilages open.

F. Postoperative Management

- Provide intensive nursing (see Precautions).
- Keep spare tracheostomy tubes at bedside (same size and one smaller).
- Replace nasogastric tube for nutrition and to avoid aerophagia.
- Suction secretions as needed to avoid plugging. For first 24 hours, be liberal with saline irrigation.
- Make sure ventilator tubing is not pulling on tracheostomy tube.
- Be aggressive with wound care so that stoma heals quickly and thereby limits granulation. Clean once a shift with half-strength peroxide and cotton swabs, then apply antibiotic ointment.
- First tracheostomy change is done by surgical team in 4 to 7 days. Thereafter weekly changes are sufficient.

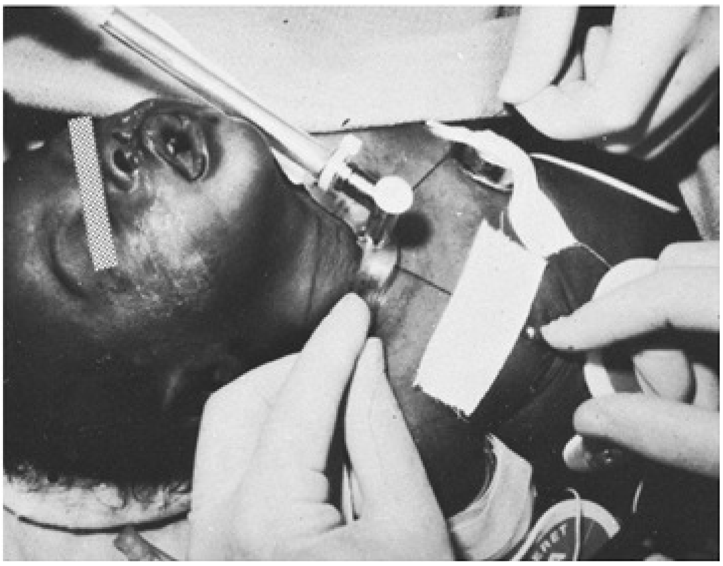

FIG. 35.4. Fixation of stay sutures. As soon as the position of the tracheostomy tube is confirmed and stomal ventilation is started, the tube may be fixed. Equal tension is kept on the stay sutures during taping. Right suture is marked to avoid confusion in future placement.

G. Early Complications (0 to 7 days)

- Bleeding: thyroid, venous, arterial
- Accidental decannulation or displacement in neck â€”stay sutures are the child's lifeline back to the trachea to allow replacement of the tube.
- Plugging of tube with secretions (Fig. 35.5)
    - Avoid by increasng humidity, saline irrigation, and suctioning.
- Infection of wound or pneumoniaâ€”avoid by local care, and by taking care of secretions.
- Air leaks
    - Pneumothorax may need chest tube
    - Pneumomediastinum serial films
    - Subcutaneous emphysema usually limited (avoid occlusive dressing)
- Tracheoesophageal fistula iatrogenic

H. Late Complications (after 1 week)

- Obstruction and decannulation remain ongoing risks that require vigilant care.
- Stomal infection and granulation â€—avoided by careful wound care
- Proximal tracheal granuloma â€”commonly occurs at the point where the tube rubs against the superior aspect of the tracheal opening, creating an obstruction between the vocal cords and the tube that can impede routine tracheostomy tube changes. This requires operative removal.
- Distal tracheal granulation â€”from overly aggressive suctioning or tube angulation causing rubbing of the tip against the tracheal wall. Hallmark sign is bloody secretions.

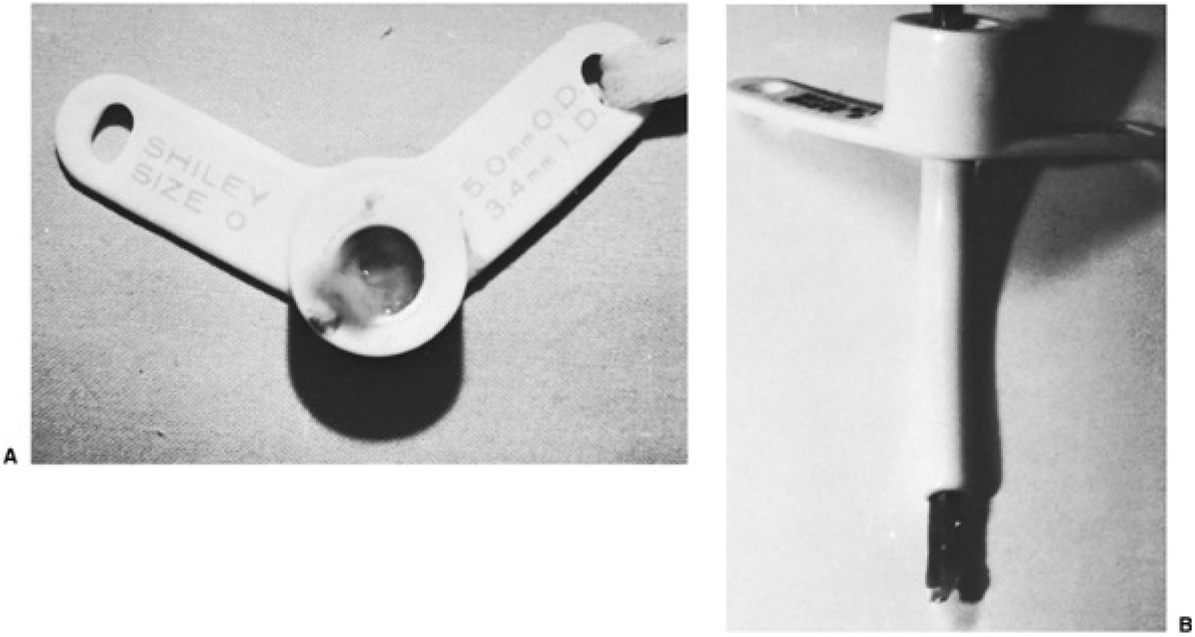

FIG. 35.5. Total obstructions of tracheostomy tubes. A: Mucus plug incompletely suctioned. B: Dry mucus plug pushed deeper by a suction catheter.

- Stenosis preventing decannulation later on
    - Part of original pathology requiring tracheostomy
    - Ongoing obliteration from active inflammatory factors
    - Consequence of procedure itself from stomal collapse or distal cicatrix

- Tracheocutaneous fistula after tube removalâ€”normal physiologic sequela, but needs secondary procedure for closure

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36-Thoracostomy Tubes

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Thoracostomy Tubes

Pulmonary air leak is an anticipated risk of mechanical ventilation. Drainage of air and/or fluid accumulation in the chest is an important and necessary skill and is often performed on an emergency basis. Thoracostomy tubes are used in neonatal intensive care units for evacuation of air or fluid from the pleural space. The procedure is often performed because of an emergency. In addition to recognizing pathologic states that necessitate chest tube insertion, intensive care specialists are frequently involved in placement, maintenance, troubleshooting, and discontinuation of chest tubes. As with any surgical procedure, complications may arise. Appropriate training and competence in the procedure may reduce the incidence of complications. This chapter reviews current indications for chest tube placement, insertion techniques, and equipment. Guidelines for chest tube maintenance and discontinuation are also discussed.
A. Indications

- Evacuation of pneumothorax
    - Tension
    - Lung collapse with ventilation/perfusion abnormality
    - Bronchopleural fistula
- Evacuation of large pleural fluid collections
    - Significant pleural effusion
    - Postoperative hemothorax
    - Empyema
    - Chylothorax
    - Extravasated fluid from a central venous line
- Extrapleural drainage after surgical repair of esophageal atresia and/or tracheoesophageal fistula

B. Contraindications

- Small air or fluid collection without significant hemodynamic symptoms

- Spontaneous pneumothorax that, in the absence of lung disease, is likely to resolve without intervention

C. Equipment
Sterile

- General all-purpose tray with no. 15 surgical blade and curved hemostats
- Gloves
- Surgical drapes
- Transillumination device
- Thoracostomy tube: Techniques of insertion differ with each type. See original references for description of technique variations (1,2 and 3).
  - Polyvinyl chloride (PVC) chest tube with or without trocar, in sizes 8, 10, and 12 French (Fr)
  - Pigtail catheter for pleural drainage (Fig. 36.1)
    - PVC with pigtail at 90-degree angle to shaft (1)
      - 8 to 10 Fr
      - Total length 10 cm
      - Insertion with or without trocar
    - Polyurethane modified vascular catheter with pigtail in same plane as shaft (2)
      - 8.5 Fr
      - Total length 15 cm
      - Insertion guide wire and dilator for insertion by Seldinger technique
    - Cook catheter (C-PPD-500/600-MP8561; Cook, Bloomington, IN, USA) (3)
      - 5 and 6 Fr
      - Cutting needle tip joined to a biopsy needle shaft with a collar that prevents the catheter from sliding up the needle during insertion
- Evacuation device
  - Infant thoracostomy tube set: Several commercially available units are appropriate for infants (Fig. 36.2).
    - Evacuation rate (4)
      - With single tube, capacity depends on level of water in chamber (cm H_2O).

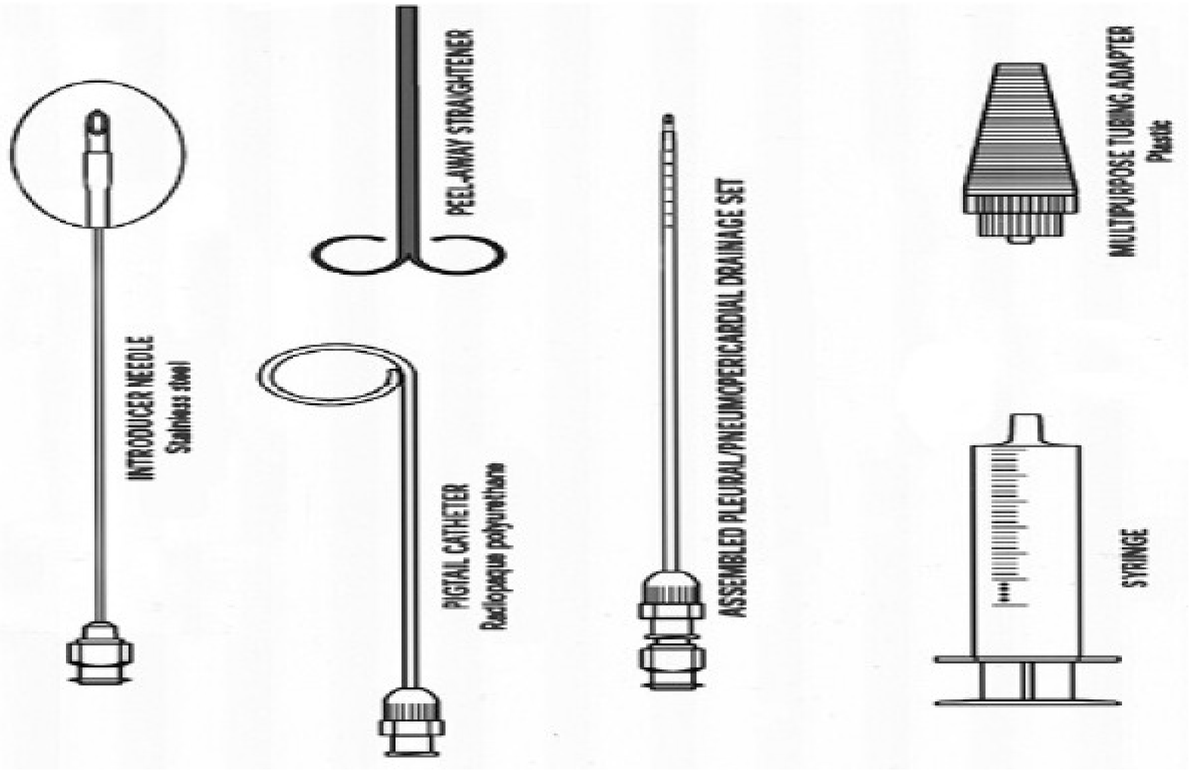
INTRODUCER NEEDLE
Stainless steel
PEEL-AWAY STRAIGHTENER
PIGTAIL CATHETER
Radiopaque polyurethane
ASSEMBLED PLEURAL/PNEUMOPERICARDIAL DRAINAGE SET
MULTIPURPOSE TUBING ADAPTER
Plastic
SYRINGE

FIG. 36.1. Pigtail catheter for pleural drainage (Fuhrman pleural drainage set). (Illustration provided by Cook Critical Care, Bloomington, IN, USA).

  - With multiple tubes, capacity also depends on applied vacuum.
- Negative pressure of 20 cm H_2O evacuates more than 4 L of air/min in experimental setting (4).
  - Appropriate starting point for most infants with lung disease on ventilators is 10 to 15 cm H_2O
  - Potentially inadequate in a case of bronchopleural fistula
  - Excessive suction pressure may draw tissue into the side holes of the chest tube and could also be potentially harmful in changing intrapulmonary air flow in presence of smaller pleural leak (always start with 10 cm H_2O).

Measured rates across bronchopleural fistulas in infants have indicated ranges from 30 to 600 mL/min (5). If suction pressure is too high, gas flow to alveoli may be diverted across a fistula. The pressure and flow applied to the endotracheal tube also directly influence flow across a fistula (5). Because there are many interactive factors influencing how much air might have to be evacuated, there can be no single best suction level for all patients; the most effective, least harmful level has to be determined for each situation (6).

- Nonabsorbable suture on small cutting needle, 4.0
- Cotton-tipped applicators
- Semipermeable transparent dressing
- Antibiotic ointment
- Petroleum gauze

Nonsterile

- Tincture of benzoin
- Â½-in adhesive tape
- Towel roll

D. Factors Influencing Efficiency of Air Evacuation

- Contiguity of air to chest tube portals; they must be patent
  - In supine infant, air accumulates in the medial, anterior, or inferior hemithorax, making low anterior location for tip of tube ideal for evacuation (7).

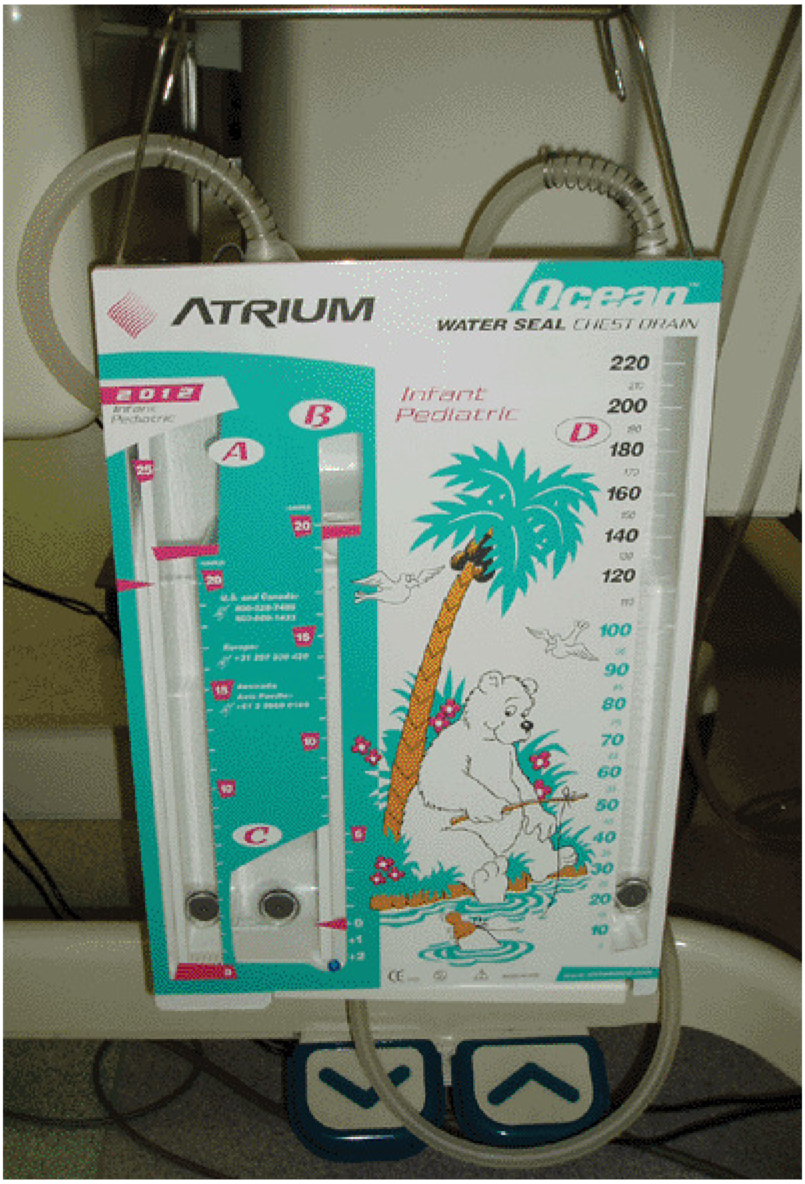
ATRIUM
Ocean
WATER SEAL CHEST DRAIN
2012
Infant Pediatric
A
B
C
D
220
200
180
160
140
120
100
90
80
70
60
50
40
30
20
10

FIG. 36.2. One model of an underwater drainage system, demonstrating the three necessary chambers. Systems now are compact and easy to set up and read. This system is set at 22 cm H_2O, which would be necessary only for a rapid rate of air accumulation.

  - Negative pressure on chest tube may draw tissue into side portals and occlude them.
- Rate of air accumulation proportional to
  - Airway flow and pressure

    Dennis et al. (8) demonstrated in experimental rabbit models that a positive end-expiratory pressure level >6 cm H_2O resulted in greater air leak than peak inspiratory pressure, up to 30 cm H_2O.

    - Size of fistula or tear
    - Infant position

      If the affected side is the dependent hemithorax and therefore is splinted, there is a lower rate of air leak than if the affected side is not dependent or is elevated (9).

- Rate of evacuation
  - Directly proportional to
    - Internal radius of chest tube (r^4)
    - Pressure gradient across tube (DP)
      - Suction pressure applied

        The negative pressure applied may affect intrapleural pressure only in the immediate vicinity of the tip of the tube (4).

      - Positive intrathoracic pressure during exhalation, spontaneous or mechanical
  - Inversely proportional to length of tube and viscosity

    Poiseuille's law regarding flow across a tube is F = DPÏ€r^4/8hl, where F = flow; DP = pressure gradient; r = radius; h = viscosity; and l = length.

E. Precautions

- Anticipate which infant is at risk of developing pulmonary air leakage and keep equipment for diagnosis and emergency evacuation at hand (6,10,11).
- Recognize that transillumination may be misleading (12,13).
  - True positive
    - Follows shape of thoracic cavity (not corona of light source)
    - Varies with respiration and position
    - Has larger area compared with corona of light at another normal site
  - False positive
    - Subcutaneous edema
    - Subcutaneous air
    - Severe pulmonary interstitial emphysema
  - False negative
    - Thick chest wall
    - Darkly pigmented skin
    - Area over air accumulation obscured by dressing/monitor probe
    - Weak light because of fiber-optic deterioration or voltage turned too low
    - Room too light
    - Abnormal color vision in observer
- Distinguish pleural air collections from skin folds, thymus, Mach effect, artifacts, or other nonpleural intrathoracic air collections on radiograph (Figs. 36.3,36.4,36.5 and 36.6) (7,14).
- Select the appropriate insertion site (Figs. 36.7 and 36.8).

  Allen et al. (15) recommend inserting the thoracostomy tube in the anterosuperior portion of the chest wall, in the first to third intercostal space at the midclavicular line, to ensure anterior placement of the chest tube tip. However, although an anterior insertion may be appropriate for the right-angled pigtail tube used by Allen et al., a properly placed lateral tube will have its tip anterior but, more important, will not leave a (more visible) scar on the anterior chest and completely avoids the nipple (see Fig. 36.19).

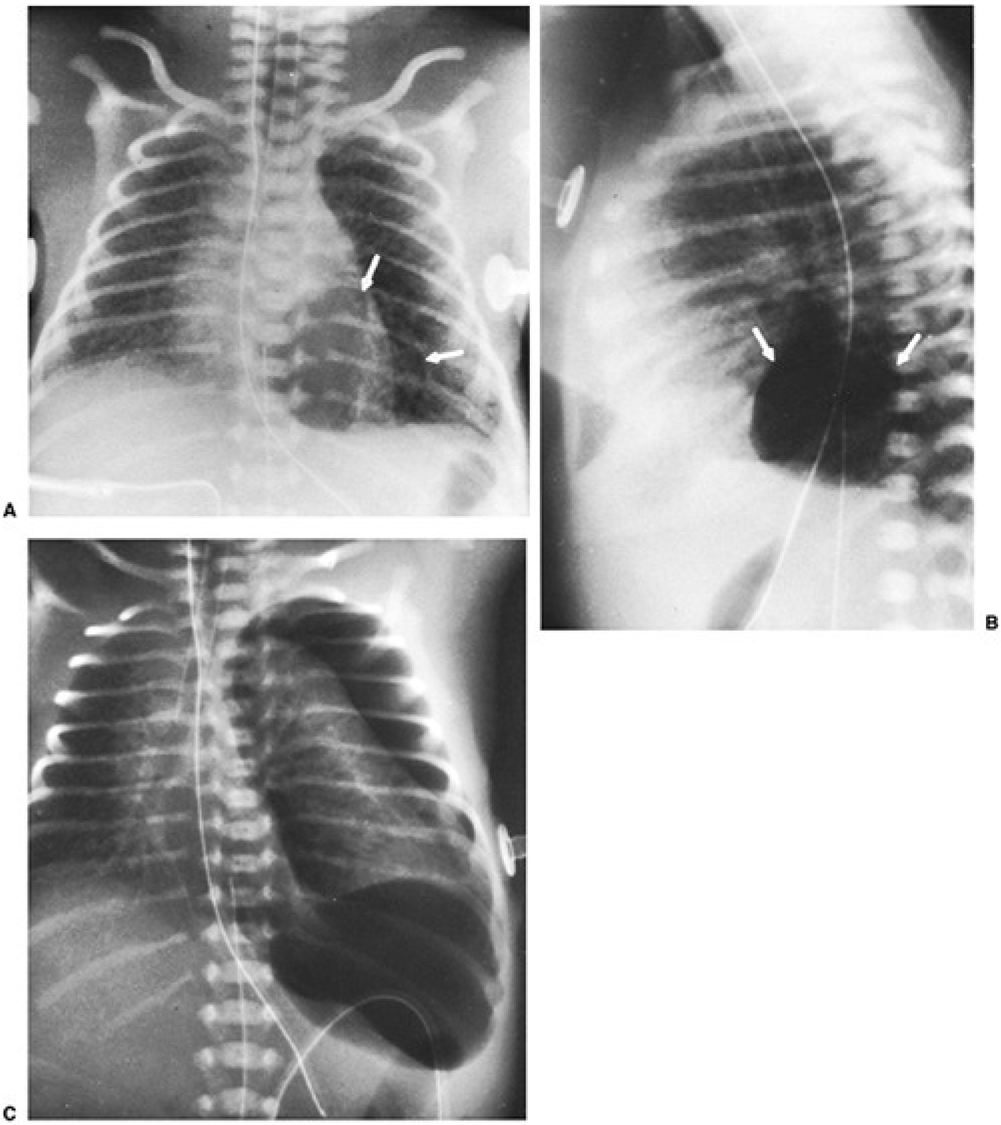

FIG. 36.3. Sequential radiographs. A: Anteroposterior radiograph demonstrating a cystic lucency at the left base behind the heart (arrows) that resembles the artifact caused by taking a film through the hole in the top of an incubator. Note also the coarse, irregular lucencies of interstitial emphysema (PIE) in the left lung. B: Lateral film showing the lucency to be real (arrows) and, in this case, a pneumomediastinum located most probably in the left inferior pulmonary ligament. C: PIE and air in the pulmonary ligament are often harbingers of impending pneumothorax, in this case, a tension pneumothorax. Note low position of endotracheal tube.

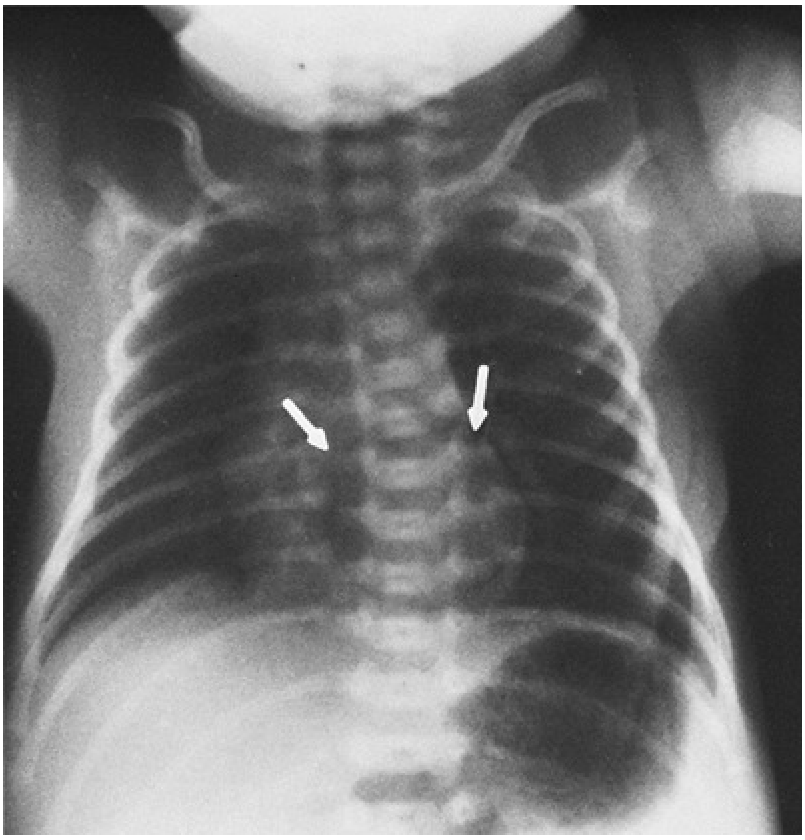

FIG. 36.4. Radiographic artifact of cystic lucency behind the heart (arrows) caused by taking film through top of incubator. The lateral film was negative, therefore excluding a cystic pulmonary lesion or air in the pulmonary ligament.

  - Reduces complications
  - Facilitates insertion of thoracostomy tube into appropriate position
    - Anteromedial tip for air collections
    - Posterior tip for fluid accumulation (Fig. 36.9A, B).
- While inserting the chest tube, allow some air to remain within pleural space as protective buffer between lung and chest wall (6).
  - Use emergency pneumothorax evacuation only if patient is critically compromised. If emergency evacuation is used, remove air only until vital signs are stable.
  - Position infant so point of entry is the most elevated area of the chest.
    - Allows air to rise to provide protective buffer.
    - Direct tip of the chest tube anteriorly toward the apex of the thorax.
- Consider the possibility that a rapid, complete evacuation may cause an abrupt increase in mean arterial blood pressure and cerebral blood velocity to undesirable, supranormal levels (16).
- Avoid positioning infant in lateral decubitus position for any longer than necessary with â€œnormalâ€□ lung dependence, thereby further compromising ventilation.
- To prevent laceration of lung parenchyma, avoid inserting needles beyond parietal pleura for diagnostic or emergency taps. Use a straight clamp perpendicular to the needle shaft to limit depth of penetration (Fig. 36.10).
- Do not use purse-string suturing of the incision site, because resulting scars tend to pucker (6,17) (see Fig. 36.19).
- Recognize that air leaks are likely to persist after initial evacuation in the presence of continuing lung disease or positive-pressure ventilation. Air leaks resolve in 50% of patients within the first 4 days after chest tube placement, and 83% resolve after 7 days (18).
  - Continue to watch for patency of the chest tube (Fig. 36.11).
  - Verify the correct position of the tube.

  - Modify positive-pressure ventilator patterns to minimize risk of further air leaks (10).
    - Decrease inspiratory time.
    - Decrease mean airway pressure.
  - Position infant with the side of the pleural gas leak dependent (9).

F. Technique (See also Procedures DVD)

Insertion of Anterior Tube for Pneumothorax

- Determine location of air collection.
  - Physical examination

    Auscultation of the small neonatal chest may be misleading because the breath sounds normally are bronchotubular and may be relatively well transmitted across an air-filled hemithorax. In addition, shift of the point of maximal impulse toward the other side is unusual in the presence of noncompliant lungs. Physical findings of acute abdominal distention, irritability, and cyanosis or a change in transthoracic impedance suggest an air leak but not its location (19,20). Supplementary diagnostic procedures are usually necessary.

  - Transillumination (12)
  - Radiograph (7,21)
- Support the infant with artificial ventilation as required. The majority of infants with a pneumothorax requiring a chest tube also need ventilatory support.
- Monitor vital signs. Move any electrodes from the operative site to alternative monitoring areas.
- Position infant with affected side elevated 60 to 75 degrees off the bed and support the back with a towel roll. Secure arm across the head, with shoulder internally rotated and extended (Fig. 36.12A).

  This position is very important because it allows air to rise to the point of tube entry into the thoracic cavity, outlines the latissimus dorsi muscle, and encourages the correct anterior direction of the tube.

- Prepare the skin with an iodophor antiseptic over the entire lateral portion of chest to the midclavicular line. Blot excess antiseptic and allow skin to dry.
-

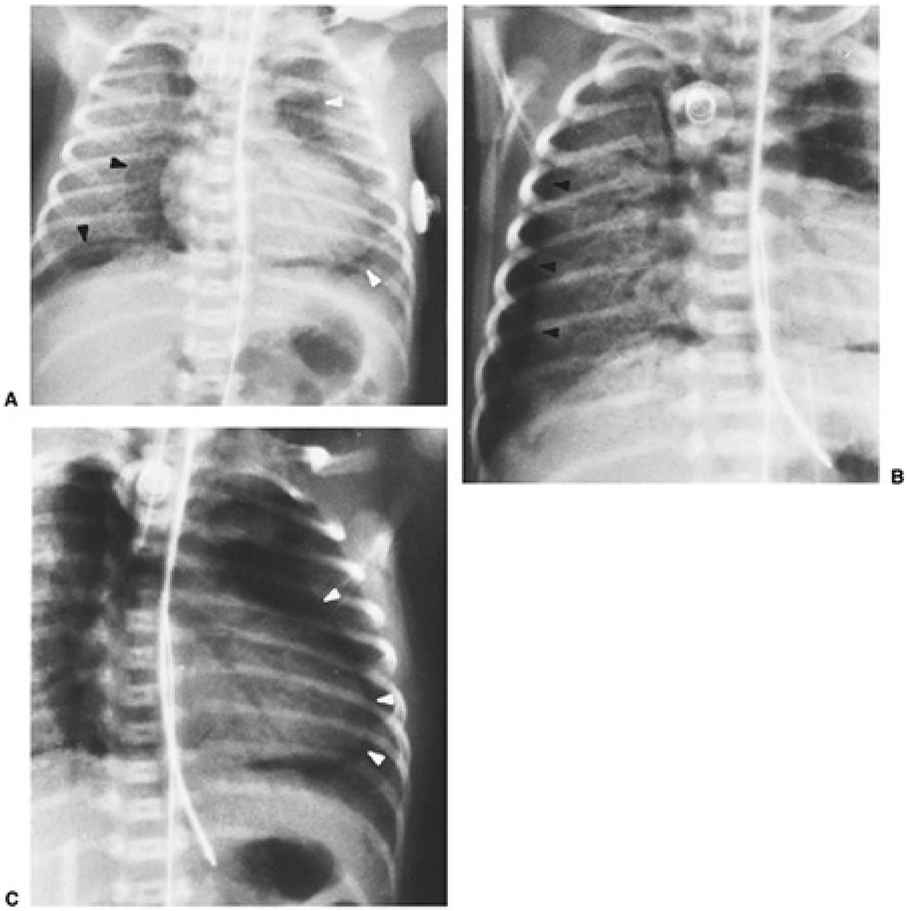

FIG. 36.5. A: Anteroposterior radiograph demonstrates ventral air over the hemidiaphragms and around the heart (arrowheads). The sometimes difficult question of pneumothorax versus pneumomediastinum is answered by the decubitus films. B: The left lateral decubitus radiograph (right side up) shows that the right-sided gas is a pneumothorax (arrowheads). C: The right decubitus film indicates that the adventitial air fails to come up over the lung and is located in the mediastinum (arrowheads). This important distinction is made obvious by the decubitus radiographs.

- Drape surgical area from third to eighth ribs and from latissimus dorsi muscle to midclavicular line (Fig. 36.12B). Using a transparent aperture drape allows continued visualization of landmarks.
- Locate essential landmarks (Fig. 36.12C).
    - Nipple and fifth intercostal spaces
    - Midaxillary line
    - Skin incision site is at point midway between midaxillary and anterior axillary lines in the fourth or fifth intercostal space. A horizontal line from the nipple is a good landmark for identifying the fourth intercostal space. Keep well away from breast tissue (22).
- Remove trocar from tube.

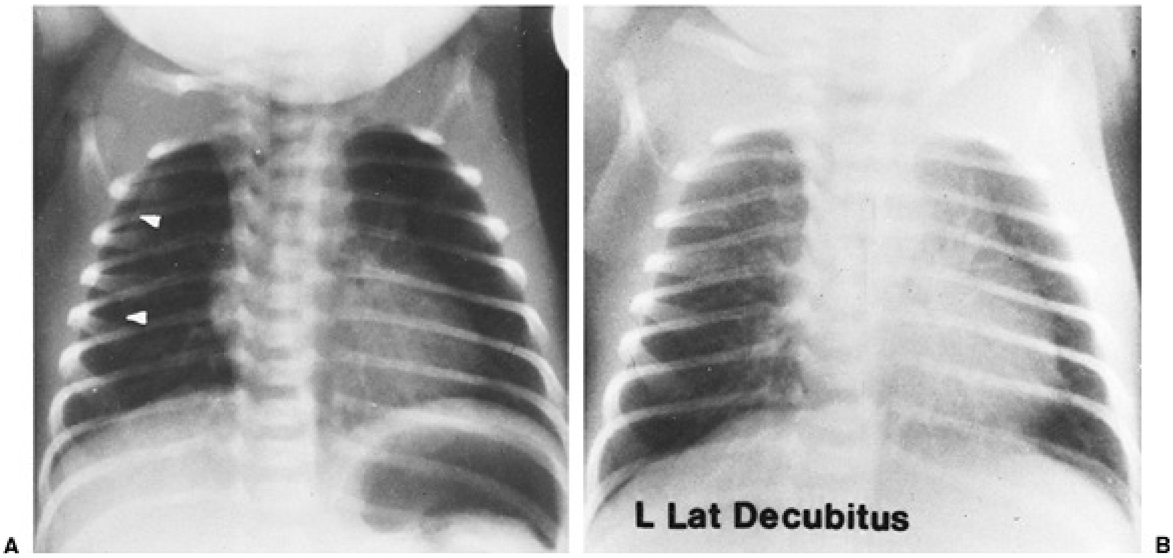

FIG. 36.6. A: On this anteroposterior supine film, there is a line that parallels the chest wall (arrowheads), which suggests the presence of a pneumothorax. B: This left decubitus film (right side up) confirms this line to be a skin fold, negative for air. When there is a question of potential adventitial air or of the anatomic location of real adventitial air, a decubitus film with the side in question up is the most important radiographic study.

We do not recommend using a trocar during tube insertion because of the greater likelihood for lung perforation. Dissection to the pleura should be performed as described here, with puncture of the pleura by the tip of the closed forceps, not by a trocar. Should a trocar be used after dissecting to the pleura, there should be a straight clamp perpendicular to the shaft at 1 to 1.5 cm from its tip to avoid penetrating too deeply (Fig. 36.10).

- Estimate length for insertion intrathoracic portion of tube (skin incision site to mid-clavicle). This should be approximately 2 to 3 cm in a small preterm infant and 3 to 4 cm in a term infant. (These are approximate guidelines only.)
- Infiltrate skin at incision site with 0.125 to 0.25 mL of 1% lidocaine.
- Using a no. 15 blade, make incision through skin the same length as chest tube diameter or no more than 0.5 to 1.0 cm (Fig. 36.12C).
- Puncture pleura immediately above the fifth rib by applying pressure with index finger (Fig. 36.12D).
    - Place the forefinger as shown in Fig 36.12D and not further forward on the forceps, to prevent the tip from plunging too deeply into the pleural space.
    - A definite give will be felt as the forceps tip penetrates the pleura; there may also be an audible rush of air.

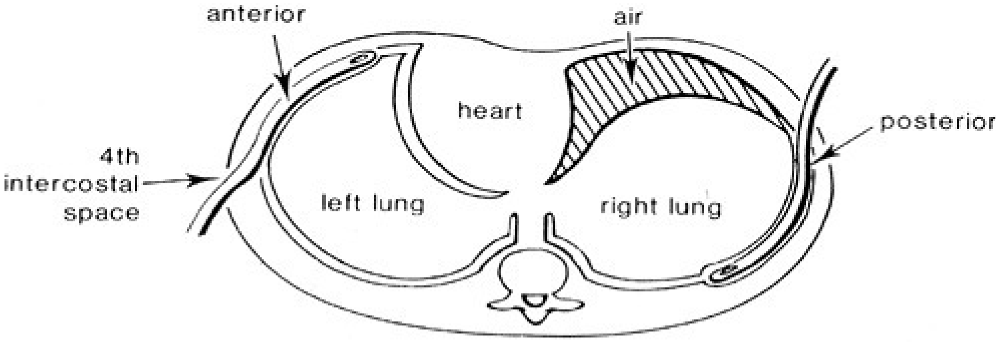

FIG. 36.7. Anterior versus posterior position of the tube for drainage of air or fluid. Because air collects anteromedially in the supine neonate, the posterior tip is less appropriate.

  - After puncturing pleura, open hemostat just wide enough to admit chest tube.
- Leaving hemostat in place, thread tube between opened tips to the predetermined depth (Fig. 36.12E).
  - Alternatively, insert closed tips of mosquito hemostat into side port of tube to its end. The disadvantage of this method is that the forceps will have to be withdrawn from the opening in the chest; it is common that the intercostal muscles then render the opening undetectable (22,23).

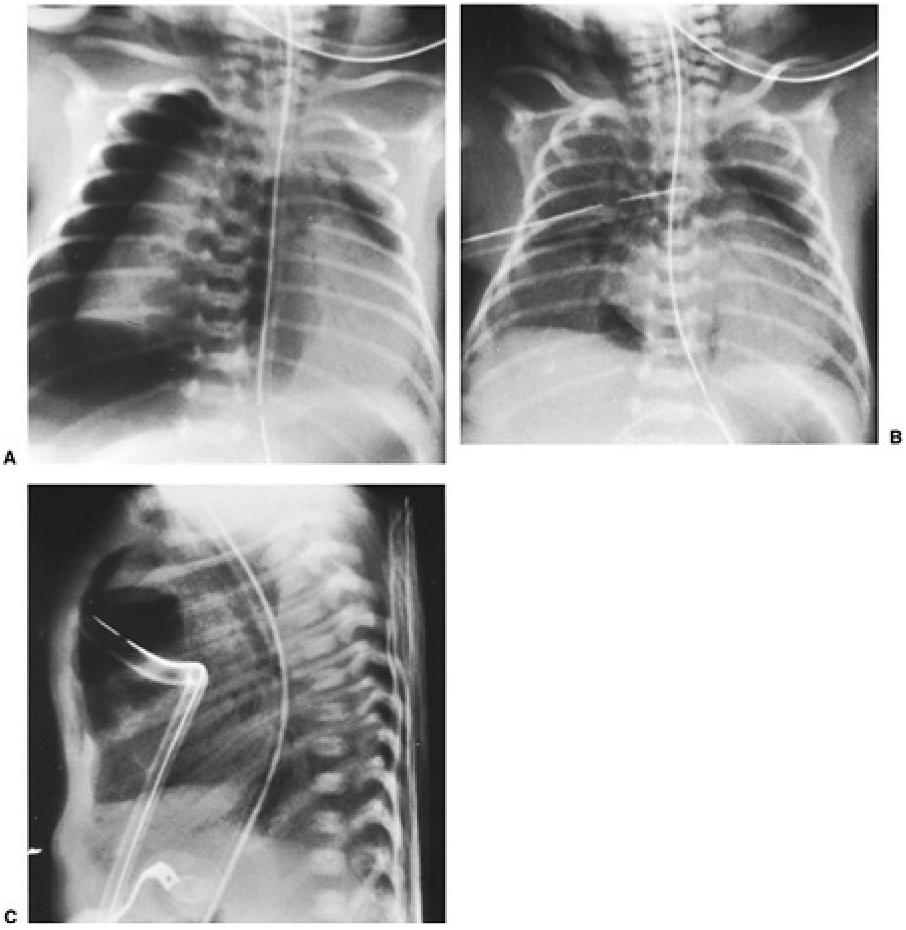

FIG. 36.8. Sequential radiographs in patient with right pneumothorax. An air collection in supine neonates (A) is most effectively treated with an anteromedial chest tube (B, C). The medial extension is falsely exaggerated by the slight right posterior oblique position of the chest. Pulling this tube back might put the side holes outside the pleural space. There is a

pneumomediastinum, most evident on the lateral view, not drained by the pleural tube. Note the nuchal air on all three films.

- Direct chest tube cephalad, toward apex of thorax (midclavicle), and advance tip to midclavicular line, ensuring that all side holes are within pleural space.
- Observe for humidity or bubbling in chest tube to verify intrapleural location.

- Connect tube to vacuum drainage system and observe fluctuations of meniscus and pattern of bubbling (Fig. 36.11). Avoid putting tension on tube.
- Secure chest tube to skin with suture (Fig. 36.13A).

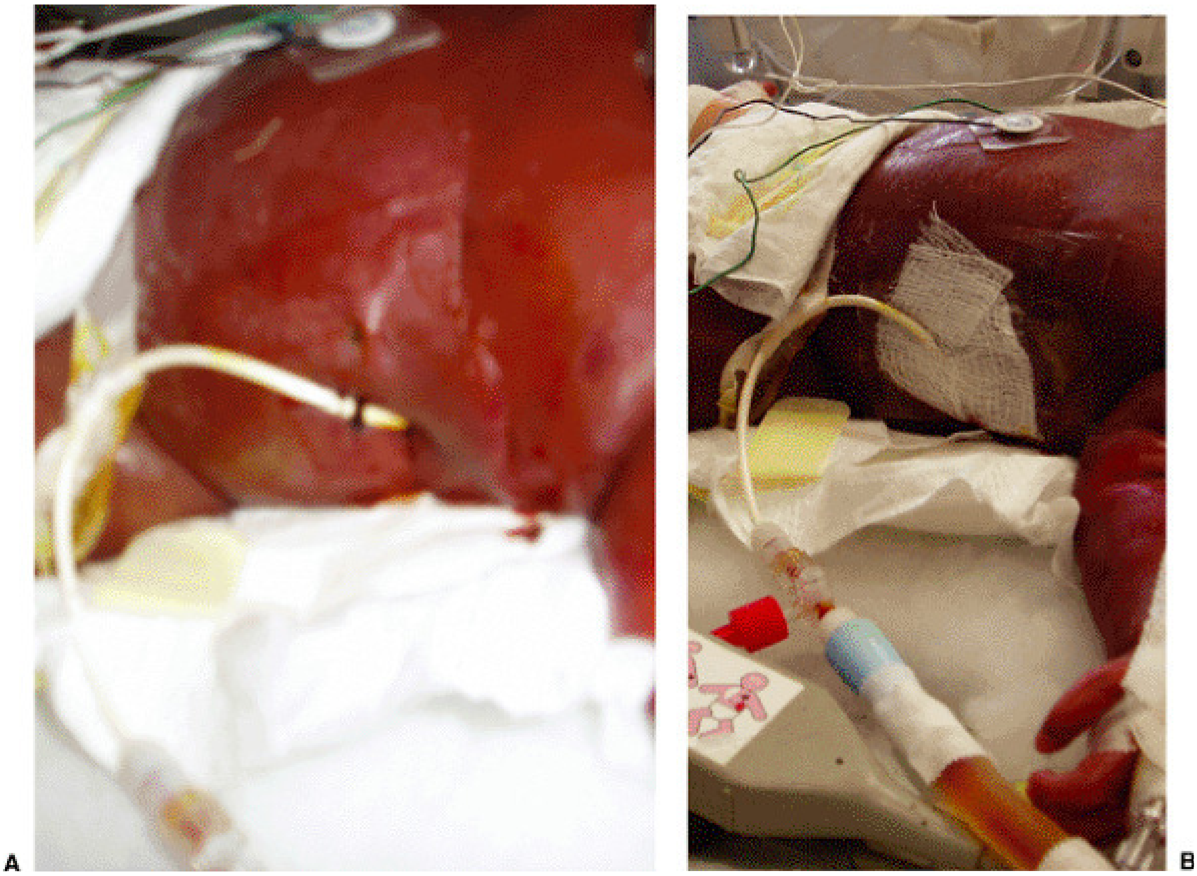

FIG. 36.9. A: Photograph of a pigtail catheter placed posteriorly for pleural fluid drainage. B: Serosanguineous pleural fluid collection into the chest tube set.

- Use one suture to close end of skin incision and make airtight seal with chest tube. Tie ends of suture around tube in alternating directions, without constricting tube.

  Because using a traditional purse-string suture to secure the tube leaves an unsightly scar, we do not recommend it. Unless skin incision has been made unnecessarily long, a single suture is usually sufficient.

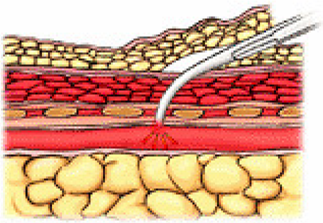

FIG. 36.10. Chest wall in cross section. If there is need to use a needle or trocar to enter the pleural space, its depth of penetration should be limited by a perpendicular clamp.

  - Apply tincture of benzoin to chest tube near chest wall and to skin several centimeters below incision. When tacky, encircle tube with a 2-in length of tape, leaving tab posterior (Fig. 36.13B).
  - Place suture through skin and tab of tape to stabilize chest tube in straight position (Fig. 36.13B).
  - Alternatively, secure tube with tape bridge (Fig. 36.14) or clear adhesive dressing (the latter may not be optimal; chest tubes tend to function optimally when allowed to exit from the skin at as close to a 90-degee angle as possible).
- Apply antibiotic ointment or petroleum gauze around skin incision. Cover with small semiporous transparent dressing.

  It is important not to cover the wound with a heavy dressing, which restricts chest wall movement, obscures tube position, and makes transillumination more difficult. If the position of tube is in doubt, secure with temporary tape bridge before covering with dressing until correct position is confirmed.

- Verify proper positioning of tube.

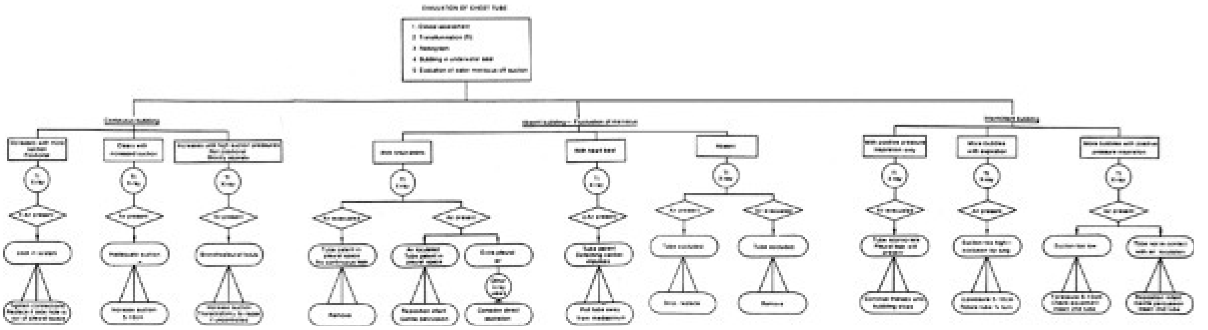

FIG. 36.11. Evaluation of a chest tube: Flow chart to determine how well a chest tube is evacuating pleural air leak and when tube should be removed.

  - Anteroposterior and lateral radiographs (6,24,25 and 26)

    Both views are recommended to detect anterior course of tube. See Tables 36.1 and 36.2 for radiographic clues on malpositions. Malpositioned tube tip results in an increased risk of complications and/or poor air evacuation. Chest radiograph should confirm that the side holes are within the chest cavity.

TABLE 36.1 Clues to Recognize Thoracostomy Perforation of the Lung

1. Bleeding from endotracheal tube
2. Continuous bubbling in underwater seal
3. Hemothorax
4. Blood return from chest tube
5. Increased density around tip of tube on radiograph
6. Persistent pneumothorax despite satisfactory position on frontal view
7. Tube lying neither anterior nor posterior to lung on lateral view
8. Tube positioned in fissure

  - Pattern of bubbling (Fig. 36.11)
- Strip tube if meniscus stops fluctuating or as air evacuation decreases. Take extreme care not to dislodge tube by holding tube firmly with one hand close to chest wall.

Insertion of Posterior Tube for Fluid Accumulation

The technique is similar to that for an anteriorly positioned tube, with the following differences.

- Position infant supine, elevating the affected side by 15 to 30 degrees from the table. Secure the arm over the head (Fig. 36.15).
- Prepare skin over lateral portion of hemithorax from anterior to posterior axillary line.

TABLE 36.2 Clues to Thoracostomy Tube Positioned in Fissure

1. Major interlobar fissure
    a. Frontal view: Upper medial hemithorax
    b. Lateral view: Oblique course posterior and upward
2. Minor fissure (on right)
    a. Horizontal course toward medial side of lung

- Make skin incision of 0.5 to 0.75 cm in length, just behind the anterior axillary line in the fourth to sixth intercostal space and following direction of rib.
    - Fourth or fifth space for high posterior tube tip
    - Sixth space for low posterior tube tip
- Taking care to position forceps tip immediately above a rib to avoid the intercostal vessels that run under the inferior surface, penetrate the pleura as described for anterior chest tube.
- Insert tube only deeply enough to place side holes within pleural space.
- Collect drainage material for culture, chemical analysis, and volume.
- Connect to underwater seal drainage system that includes a specimen trap.
- Strip tube regularly.
- Monitor and correct any imbalance caused by loss of fluid, electrolytes, protein, fats, or lymphocytes.

Removal of Thoracostomy Tube

- Ascertain that tube is no longer functioning or needed.
    - Evaluate as suggested in Fig. 36.11.
    - Leave chest tube connected to water seal without suction for 2 to 12 hours. Do not clamp tube.
        - Transilluminate to detect reaccumulation.
        - Obtain radiograph.
    - Document absence of significant drainage.
- Assemble equipment.
    - Antiseptic solution
    - Sterile gloves
    - Scissors
    - Forceps
    - Petroleum gauze cut and compressed to 2-cm diameter
    - Gauze pads, 2 x 2 in
    - 1-in tape
- Cleanse skin in area of chest tube with antiseptic.
- Release tape and suture holding tube in place. Leave wound suture intact if skin is not inflamed.
- Palpate pleural entry site and hold finger over it to prevent air from entering chest as tube is withdrawn until gauze is applied. After removing tube, approximate wound edges and place petroleum gauze over incision. Keep pressure on pleural wound until dressing is in place.

- Cover petroleum gauze with dry, sterile gauze. Limit taping to as small an area as possible so that transillumination will be possible.
- Remove sutures when healing is complete.

G. Complications

- Misdiagnosis with inappropriate placement
- Burn from transillumination devices (27)

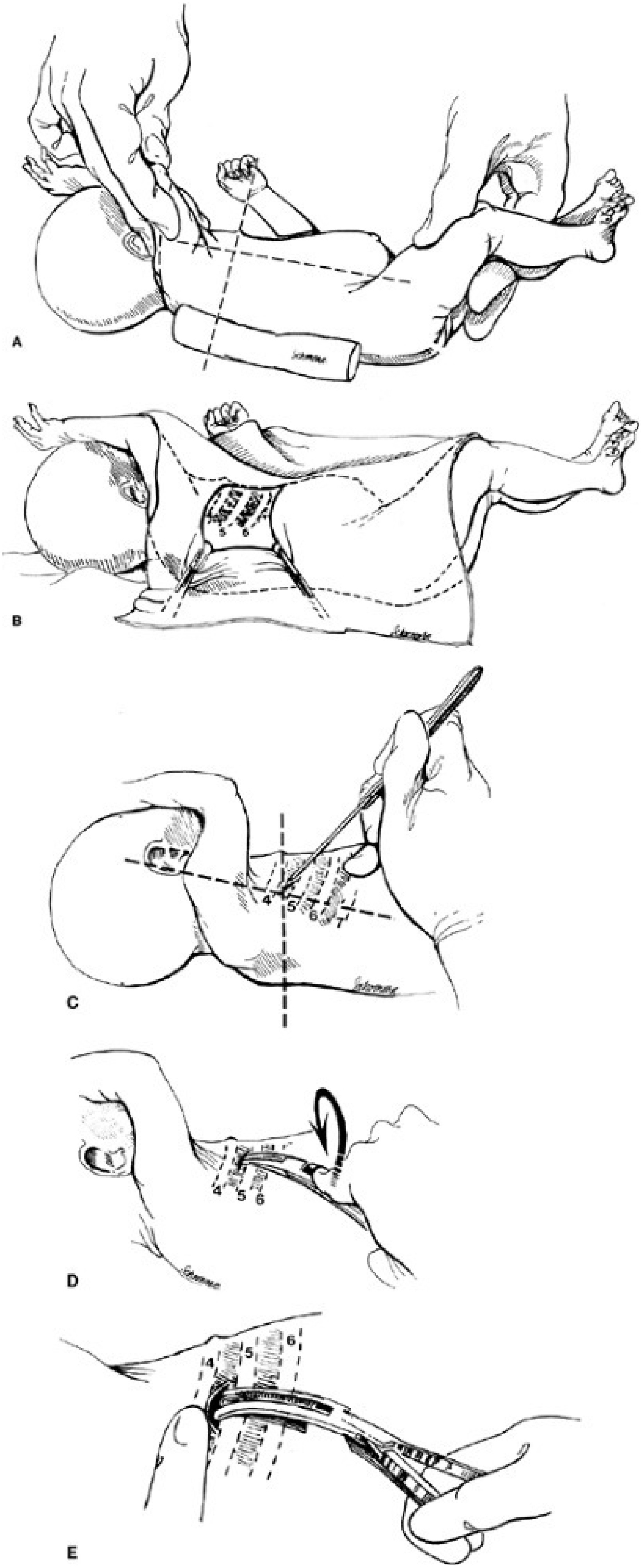
A
B
5
6
C
4
5
6
7
D
4
5
6
E
4
5
6

FIG. 36.12. Insertion of a soft chest tube. A: Position the infant with back support so the point of tube entry will be highest. Fix arm over the head without externally rotating it. Note the midaxillary (MA) line and the line from the nipple through the fourth intercostal space (ICS). B: Drape so head of the infant is visible. C: Same landmarks without the drape, showing the incision in the fourth ICS in the MA line with entry into the chest at the intersection of the nipple line and the MA line. D: Turning the hemostat to puncture into the pleura in the fourth ICS. E: With the index finger marking the fourth ICS puncture site, the tube may now be passed between the hemostat blades, along the tunnel into the pleural space.

- Trauma
  - Lung laceration or perforation (28,29) (Fig. 36.16)
  - Perforation and hemorrhage from a major vessel (axillary, pulmonary, intercostal, internal mammary) (15,30) (Fig. 36.17)
  - Puncture of viscus within path of tube (Fig. 36.18)
  - Residual scarring (17) (Fig. 36.19)
  - Permanent damage to breast tissue (17)
  - Chylothorax (31)
- Nerve damage
  - Horner syndrome caused by pressure from tip of right-sided, posterior chest tube near second thoracic ganglion at first thoracic intervertebral space (32)
  - Diaphragmatic paralysis or eventration from phrenic nerve injury (33,34 and 35)
- Misplacement of tube
  - Tube outside pleural cavity in subcutaneous placement (Fig. 36.20)
  - Side hole outside pleural space (Fig. 36.21)
  - Tip across anterior mediastinum (Fig. 36.22)
- Equipment malfunction
  - Blockage of tube by proteinaceous or hemorrhagic material
  - Leak in evacuation system, usually at connection sites
  - Inappropriate suction pressures (36,37) (Fig. 36.11)
    - Excessive pressure
      - Aggravation of leak across bronchopleural fistula
      - Interference with gas exchange
      - Suction of lung parenchyma against holes of tube
    - Inadequate pressure with reaccumulation
- Infection
  - Cellulitis
  - Inoculation of pleura with skin organisms including Candida (38)
- Subcutaneous emphysema secondary to leak of tension pneumothorax through pleural opening

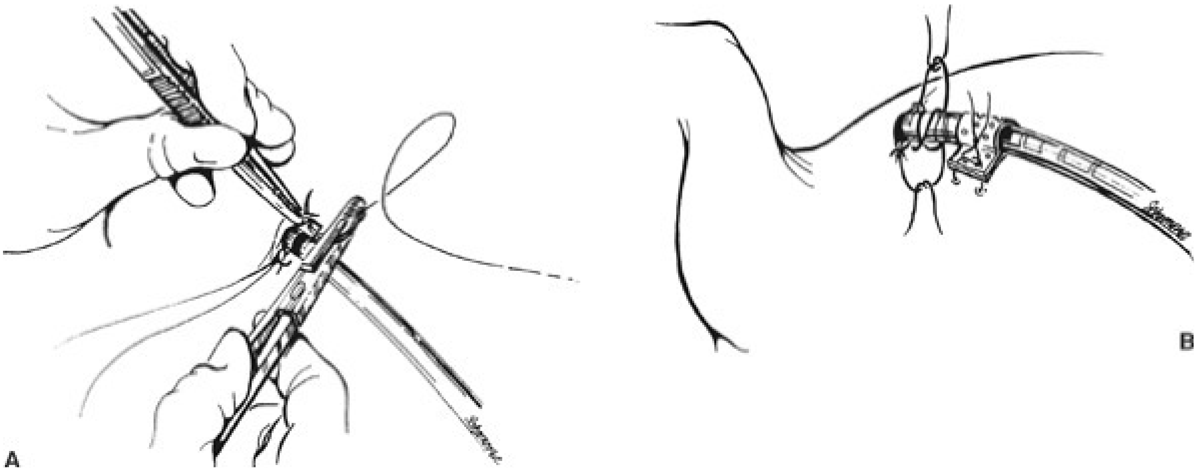

FIG. 36.13. Securing a chest tube. A: Make the incision site airtight with the tube. Do not use a purse-string suture around the incision, because it will form a puckered scar. The initial incision should be made small enough to require only a single suture. B: After painting the tube and skin with benzoin, encircle the suture around the tube or attach a bandage and suture it to the skin.

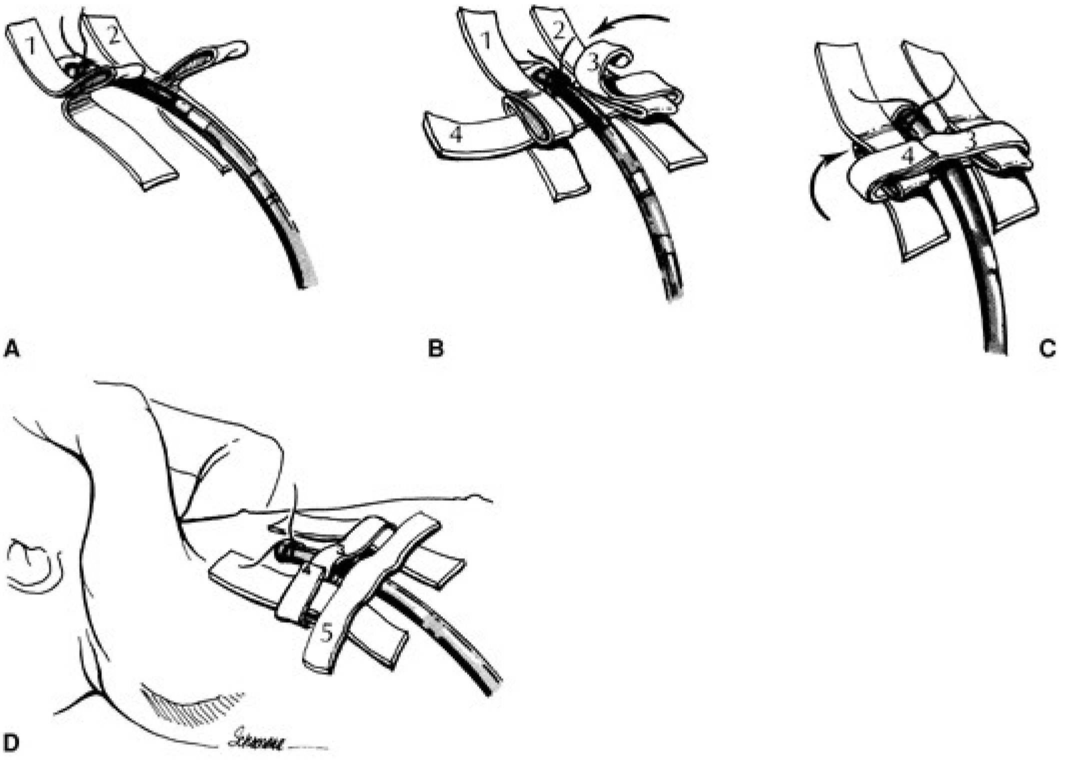

FIG. 36.14. Tape bridge. A: Two tape towers. B, C: Bridge under the tube and towers overlapping on top. D: Additional cross tape to keep the chest tube flat without kinking.

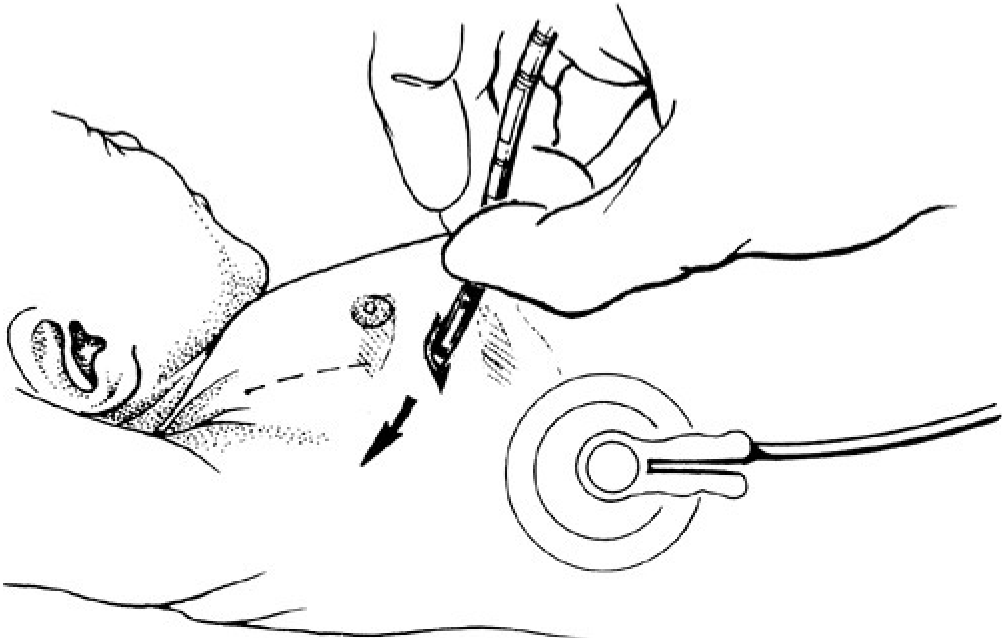

FIG. 36.15. Insertion of a posterior chest tube. With the infant supine, the incision is in or just below the anterior axillary line with the tube entry into the pleura more posteriorly Take care to enter pleural space over the top of a rib.

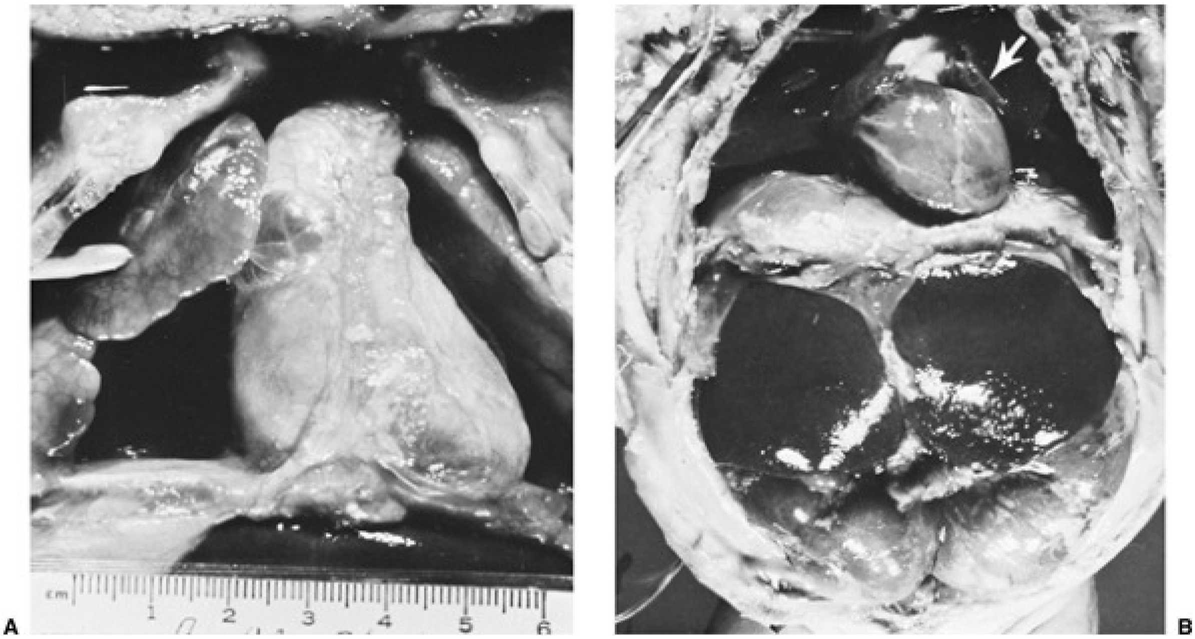

FIG. 36.16. Postmortem examination of infants who died with uncontrolled air leaks. A: Perforation of the right superior lobe by a chest tube inserted without a trocar, demonstrating that virtually any tube can penetrate into the lung. B: Perforation of the left upper lobe by a chest tube (arrow).

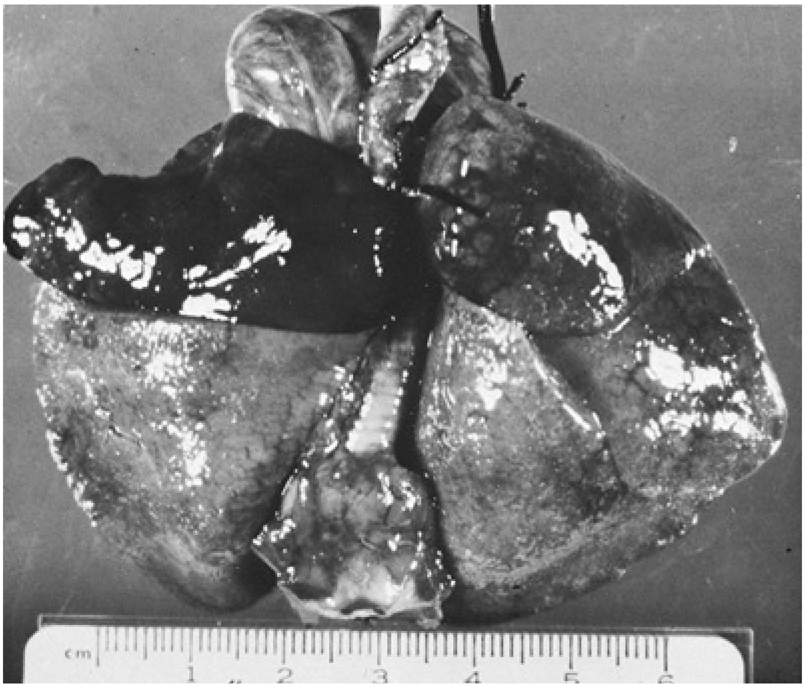

FIG. 36.17. Posterior view of thoracic organs. Traumatic hemorrhage of the left upper lobe was due to perforation by a thoracostomy tube.

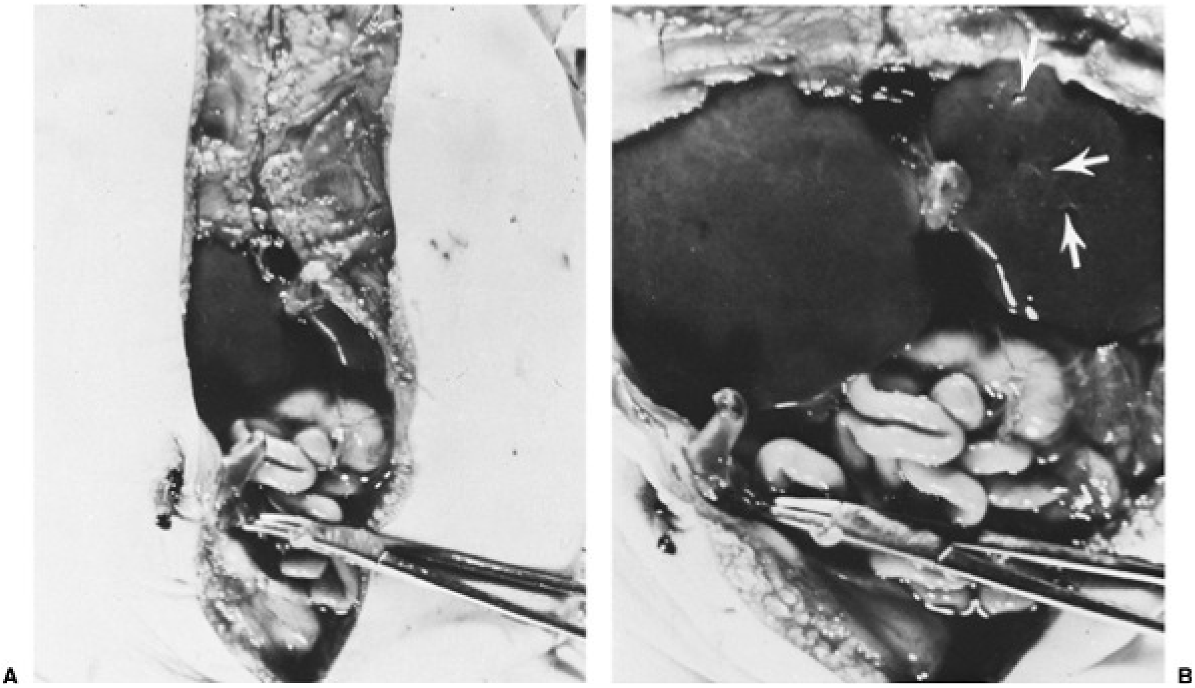

FIG. 36.18. Postmortem examination of an infant with bilateral pneumothorax, pneumomediastinum, and pneumoperitoneum secondary to pulmonary air leaks. Attempted needle aspirations, as seen by multiple skin puncture sites of the pneumomediastinum and pneumothorax (A), resulted in needle punctures of the liver (arrows, B) with peritoneal hemorrhage.

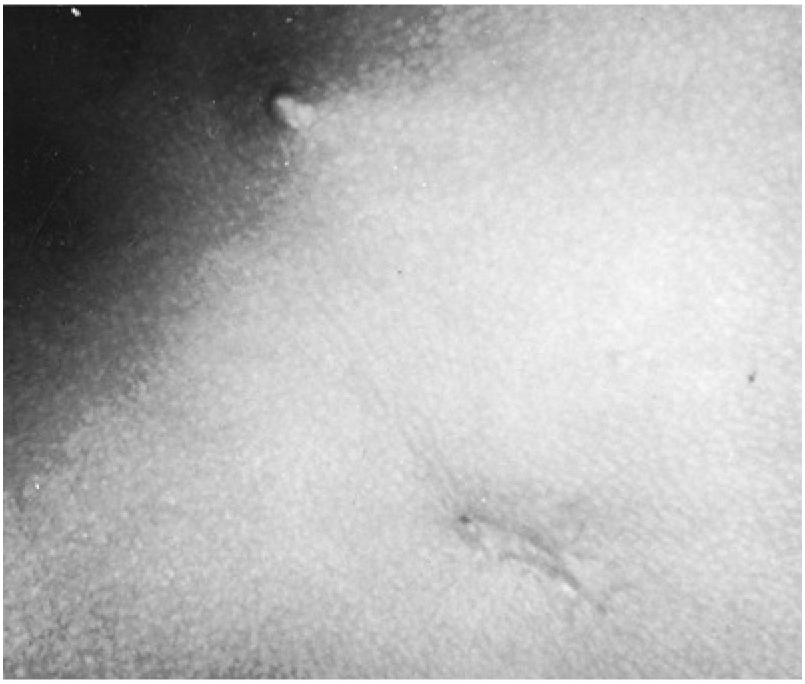

FIG. 36.19. Scar from thoracostomy insertion, emphasizing the importance of avoiding the breast area. Massage of a healed wound with cocoa butter helps break down adhesions that lead to dimpling at the scar.

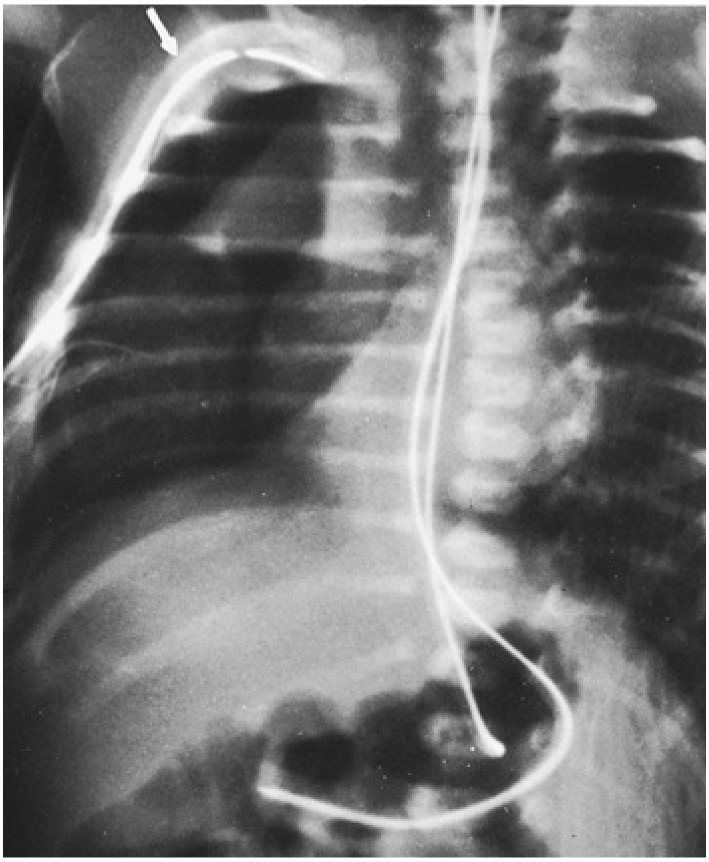

FIG. 36.20. The thoracostomy tube is completely outside the pleural space on this slightly oblique chest film. Note that the long feeding tube is not in an appropriate position for transpyloric feeding. Indwelling tubes may dislodge when other emergency procedures are performed.

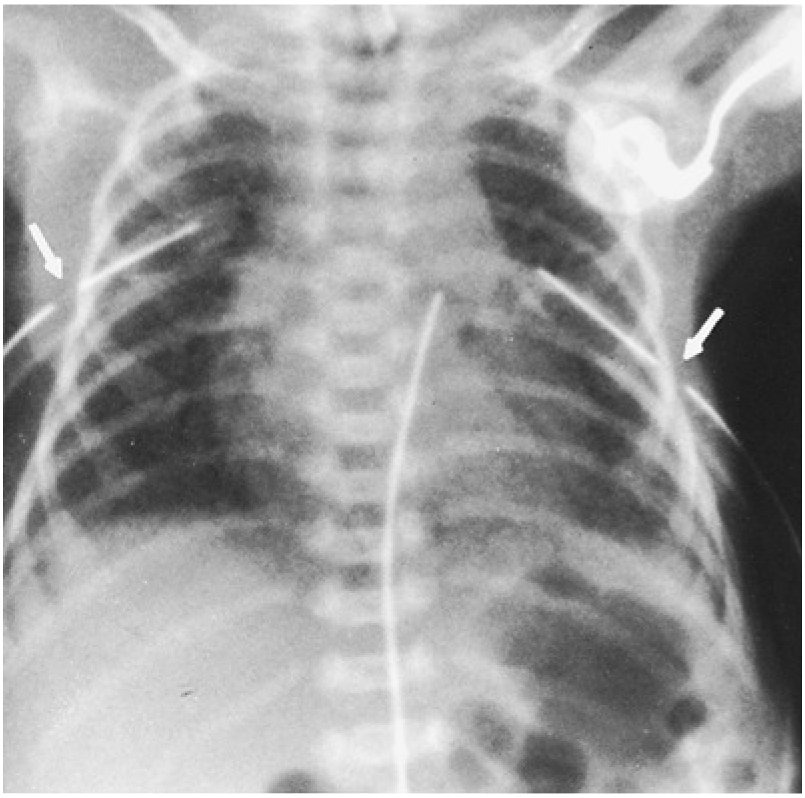

FIG. 36.21. The side holes of both thoracostomy tubes are outside the pleural space on this radiograph.

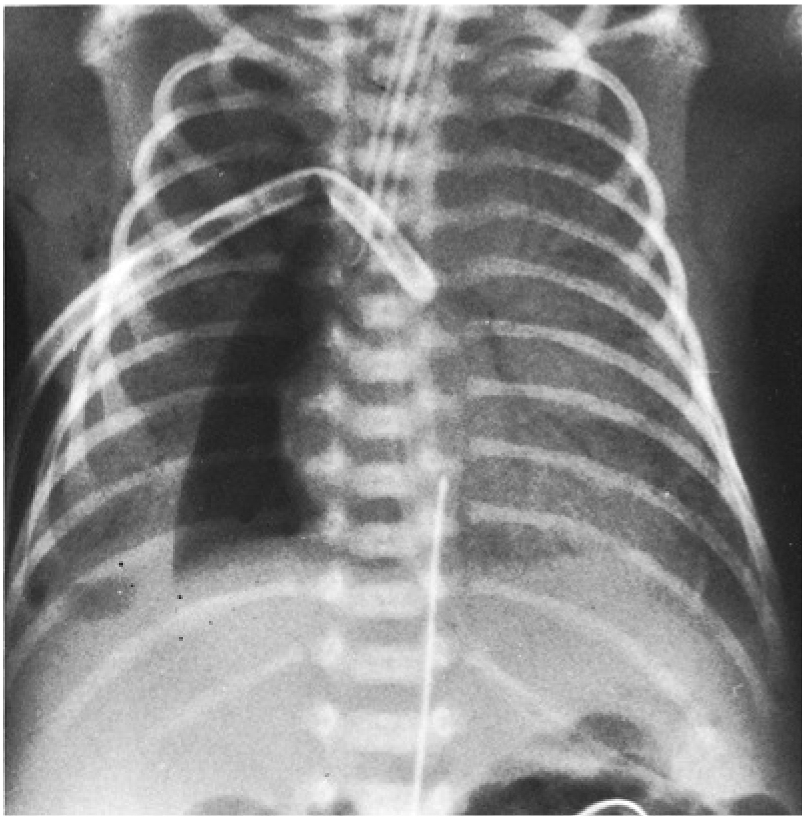

FIG. 36.22. The tip of the thoracostomy tube has been advanced too far medially and is kinked against the mediastinum. Withdrawing the tube 1 or 2 cm would improve drainage at the medial pneumothorax. Note the endotracheal tube tip in the right mainstem bronchus.

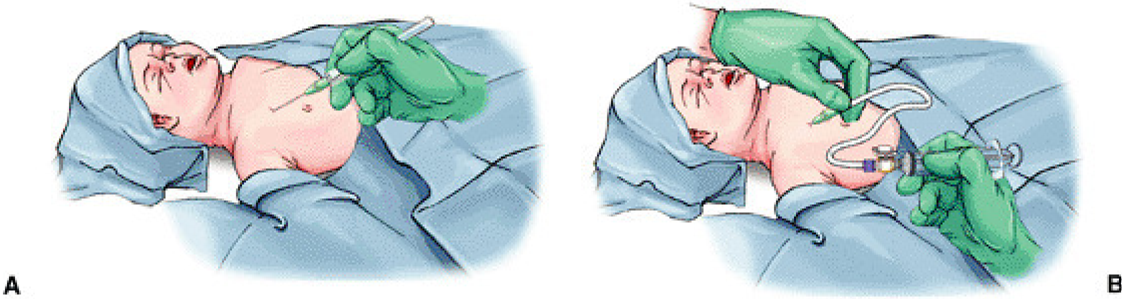

FIG. 36.23. Emergency evacuation with a vascular cannula. Puncture the skin and enter the pleura at a 45-degree angle immediately above a rib.

- Aortic obstruction with posterior tube (39)
- Loss of contents of pleural fluid
  - Water, electrolytes, and protein (effusion)
  - Lymphocytes and chylomicrons (chylothorax)

Emergency Evacuation of Air Leaks

Life-threatening air accumulations require emergency evacuation. This provides temporary relief to the patient while preparing for thoracostomy tube placement. The following techniques using modified equipment are less traumatic than using straight needles or scalp vein sets. We suggest using an anterior approach for emergency evacuation because position will not interfere with the preparation of the lateral chest site for an indwelling chest tube.

Tubes used for emergency evacuation require suction pressures as high as 30 to 60 cm H_2O to overcome the resistance of their small diameters (40). This requirement and their tendency to occlude make these cannulas unreliable for continuous drainage of a significant air leak.

A. Indications

Temporary evacuation of life-threatening air accumulations while preparing for permanent tube placement

B. Contraindications

- When patient's vital signs are stable enough to allow placement of permanent thoracostomy tube without prior emergency evacuation
- When air collection is likely to resolve spontaneously without patient compromise (nontension pneumothorax).

Use of Angiocatheter (41)

A. Equipment

- Sterile gloves
- Antiseptic solution
- 18- to 20-gauge angiocatheter
- Intravenous extension tubing
- Three-way stopcock
- 10- and 20-mL syringes

B. Technique

- Prepare skin of appropriate hemithorax with antiseptic.
- Connect male end of three-way stopcock to female end of intravenous extension tubing. Connect syringe to three-way stopcock.
- Insert angiocatheter at point that is
    - at a 45-degree angle to skin, directed cephalad
    - in second, fourth, or fifth intercostal space, just over top of rib, well above or below the areolar of the breast
    - in midclavicular line (Fig. 36.23A)
- As angiocatheter enters pleural space, decrease angle to 15 degrees above chest wall and slide cannula in while removing stylet (Fig. 36.23A).
- Attach male end of intravenous extension tubing to angiocatheter, open stopcock, and evacuate air with syringe (Fig. 36.23B).
- Continue evacuation as patient's condition warrants while preparing for permanent tube placement.
- Cover insertion site with petroleum gauze and small dressing after procedure.

Diagnostic Tap of Pleural Fluid

Follow the procedure for the insertion of a posterior chest tube, with the following differences.

A. Differences

- Use an angiocatheter, 20 gauge.
- Position patient without elevating side of fluid collection. It will be necessary to turn the affected side down only if quantity of fluid is small.
- Select insertion site in anterior or midaxillary lines below breast tissue for diffuse pleural collections. Direct catheter posteriorly after penetrating into pleural space.
- Keep system closed to prevent leakage of air into pleural space.

Anterior Mediastinal Drainage

Most mediastinal air collections cause only mild symptoms and are not under enough tension to require drainage. Their presence often precedes tension pneumothorax in the presence of lung disease and positive-pressure ventilation. Posterior mediastinal tube insertion, as described in the literature (42), is rarely required.

A. Indications

- Significant air accumulation with physiologic compromise (43)
    - Increased intracranial pressure (44)
    - Poor cardiac output because of impeded venous return
    - Critical interference with artificial ventilation
        - Competition with lungs for thoracic volume
        - Negative effect on pulmonary compliance
- Drainage of fluid
    - Mediastinitis after esophageal perforation
    - Postoperative

B. Contraindications

None absolute

C. Equipment

- Transillumination device with sterile transparent bag to cover tip
- Antiseptic for skin preparation
- Sterile gauze pads
- Sterile aperture drapes
- Surgical gloves
- 11 surgical blade
- Local anesthetic, as required
- Curved mosquito hemostat
- Drainage tube (see equipment for emergency evacuation of air leaks)
    - 10-Fr soft thoracostomy tube
    - Intravenous cannula system
        - 14- to 16-gauge angiocatheter
        - Intravenous extension tubing
        - Three-way stopcock
- 10- to 20-mL syringe
- Â½-in adhesive tape
- 4-0 nonabsorbable suture on small cutting needle with needle holder
- Connecting tubing and underwater suction device for indwelling tube

D. Precautions and Complications

The problems encountered in evacuating material from the mediastinum are similar to those encountered in placement of chest tubes. In contrast to tension pneumothorax, mediastinal collections tend to accumulate more gradually. For this reason, careful preparation of the patient and use of sterile technique are possible and essential. Refer to E and G under Thoracostomy Tubes at the beginning of this chapter for precautions and complications.

E. Technique

Drainage for longer than 12 hours normally dictates placing a 10- to 12-Fr tube by direct dissection because smaller tubes occlude readily. Select indwelling tubes only in the presence of significant lung disease or mediastinitis, where continued accumulations are anticipated. Remove the tubes as soon as possible because of the risks for infection.

Soft Mediastinal Tube Insertion

- Follow sterile technique throughout.
- Monitor infant for vital signs and oxygenation.

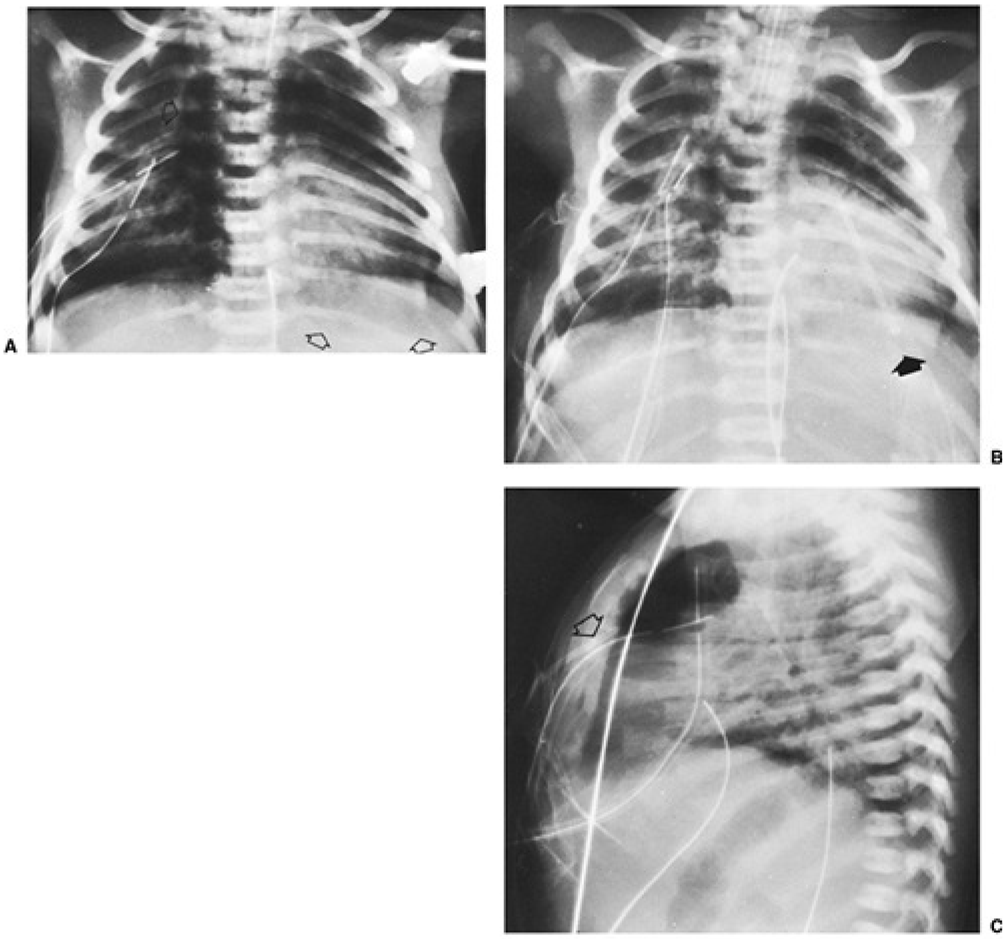

FIG. 36.24. Sequential radiographs. A: Tension pneumomediastinum (arrows). A mediastinal collection this massive is unusual. B: Successful drainage tube (arrow). C: The apparent slipping of the mediastinal cannula (arrow) is an artifact of patient rotation on this lateral view. There is still mediastinal air superiorly, but there was no patient compromise at this time.

- Determine by transillumination or radiograph the region of maximal mediastinal air accumulation (Fig. 36.24).
- Cover tip of transillumination light with sterile, clear plastic bag for use after skin preparation.
- Cleanse skin with antiseptic.
- Drape patient with aperture drape without obscuring infant.
- Infiltrate insertion site with 0.25 mL of local anesthetic.
- With no. 11 blade, make small stab wound through skin at subxiphoid.
- Using curved mosquito hemostat, dissect in the midline at 30-degree angle to chest wall in cephalad direction until entering mediastinal space. The mediastinum under tension should bulge downward.
- Insert soft chest tube into dissected tunnel, and direct tube cephalad and toward area of maximal transillumination.
- Observe tube for air rush or condensation while completing insertion. If loculations are evident, break them up with blunt dissection.
- Connect to closed drainage system at vacuum of 5 cm H_2O, and increase to 10 cm H_2O if necessary.

  Accumulation in mediastinum is usually relatively slow; therefore, lower suction pressures are effective.

  - Use low pressure to keep tube side holes patent while clearing air collection.
  - Monitor efficacy by radiograph and transillumination (Fig. 36.24).
- Secure tube with suture, and tape as for thoracostomy tubes.

- If drainage stops with significant accumulation still evident on transillumination or radiograph:
  - Verify that accumulation is in mediastinum by lateral decubitus and lateral radiographs.
  - Verify tube position on radiographs.
  - Rotate tube.
  - Aspirate, but do not irrigate, tube; reattach to continuous drainage.
  - Change position of infant to move air toward tube.

Temporary Mediastinal Drainage with Intravenous Cannula

- Assemble equipment and prepare patient as for insertion by mediastinal dissection.
- Make a small stab wound in subxiphoid notch.

  Mediastinal air under tension should be located in this area, pushing the liver and heart away from needle tip.

- Insert cannula with stylet at 45-degree angle to chest wall in cephalad direction.
- As soon as cannula passes through skin, lower cannula to 30 degrees from skin.
- Remove stylet, and attach connecting tubing, stopcock, and syringe.
- Advance cannula into mediastinal space cephalad and medially but toward area of maximal transillumination. Aspirate while advancing, and monitor cardiac tracing. Stop insertion if there is resistance, blood, or arrhythmia.
- Secure cannula in effective position, and attach intravenous extension tubing to underwater drainage system with suction pressure of 10 cm H_2O. The smaller cannula will require higher suction pressures unless the air accumulates slowly. Because air loculates within the mediastinum and the side holes occlude easily, small catheters are rarely effective for anything other than acute relief of tension. Remove cannula as soon as possible.

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37-Pericardiocentesis

Alan Benheim

A. Definitions

- Pericardium
  - A double layer of mesothelial lining surrounding the heart, consisting of the visceral pericardium on the epicardial surface and the parietal pericardium as an outer layer
  - Between the two layers there is normally a small amount of pericardial fluid (typically <5 mL for a neonate) that is thought to reduce friction.
- Pneumopericardium
  - Collection of air in the pericardial space
- Pericardial effusion
  - Accumulation of excess fluid in the pericardial space
- Pericardiocentesis
  - A procedure to remove air or excess fluid from the pericardial space, usually through a needle, small cannula, or drainage catheter
- Pericardial drain
  - A catheter or other drainage device left in place to allow intermittent or continuous evacuation of air or fluid from the pericardial space
  - Placed in select situations with recurring accumulation of air or fluid in the pericardial space
- Tamponade
  - Clinical condition with limited cardiac output because of external restriction of expansion of the heart, preventing normal cardiac filling, resulting in a decreased stroke volume and impaired cardiac output
  - May be caused by:
    - Fluid or air in the pericardial space
    - Abnormalities of the pericardium (restrictive or constrictive)
    - Increased intrathoracic pressure associated with obstructive airway lung disease or tension pneumothorax
- Pulsus paradoxus (Fig. 37.1)
  - Respiratory variation in blood pressure, with a decrease in systolic blood pressure during inspiration during spontaneous respiration. (During positive-pressure ventilation, this is reversed, with a rise in systolic pressure during inspiration.)
  - This finding occurs during tamponade.

B. Purpose

- To evacuate air to relieve cardiac tamponade
- To evacuate fluid to relieve cardiac tamponade

- To obtain fluid for diagnostic studies

C. Background

- The heart lies within a closed space, covered by the pericardium, which consists of an inner visceral layer and an outer parietal layer. The pericardial space is between these two layers. Ordinarily, the pericardial space of a neonate has <5 mL of pericardial fluid. This fluid acts as a lubricant to allow the heart to move with minimal friction. If the pericardial space fills with excess fluid, or if air accumulates, then the heart itself has less space available, and the pressure within the pericardium increases. This restricts venous return and impairs cardiac filling. This decrease in venous return and cardiac filling results in a reduced cardiac output. This clinical situation is called cardiac tamponade (1, 2, 3, 4 and 5).
- Neonates are at risk for cardiac tamponade
    - Accumulation of air dissecting into the pericardium from the respiratory system (Fig. 37.2) (4, 5, 6 and 7)
    - Pericardial fluid accumulation due to perforation or transudate from umbilical or percutaneous central venous catheter (Fig. 37.3) (1, 8, 9, 10, 11 and 12)
    - Cannulation for extracorporeal membrane oxygenation (13, 14)
    - Cardiac catheterization, either diagnostic or therapeutic (15)
    - Postoperative pericardial hemorrhage following cardiac surgery (2, 16)
    - Postpericardiotomy syndrome, typically 1 to 3 weeks after cardiac surgery (2, 16, 17)
    - Pericardial effusion as part of generalized edema/hydrops (3, 16)
    - Pericardial effusions due to infectious or autoimmune causes are less common in neonates than in older children.
- Clinical signs of cardiac tamponade may evolve gradually or rapidly (1, 3, 18).
- The primary therapy for cardiac tamponade is to evacuate the pericardial space; volume and pressors may be of transient benefit, but do not usually result in sustained clinical improvement (1, 8, 12, 16, 19).
- Cardiac tamponade may require urgent treatment with pericardiocentesis in infants with severe hemodynamic compromise (1, 16, 17).

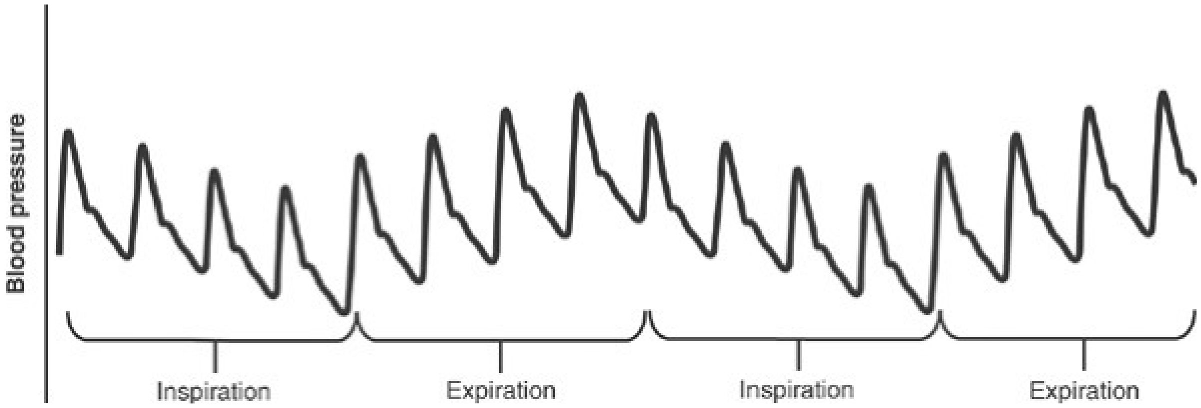


FIG. 37.1. Pulsus paradoxus.

D. Indications (1, 12, 15, 16 and 17)

- Cardiac tamponade due to pneumopericardium
- Cardiac tamponade due to pericardial fluid
- Aspiration of pericardial fluid for diagnostic studies

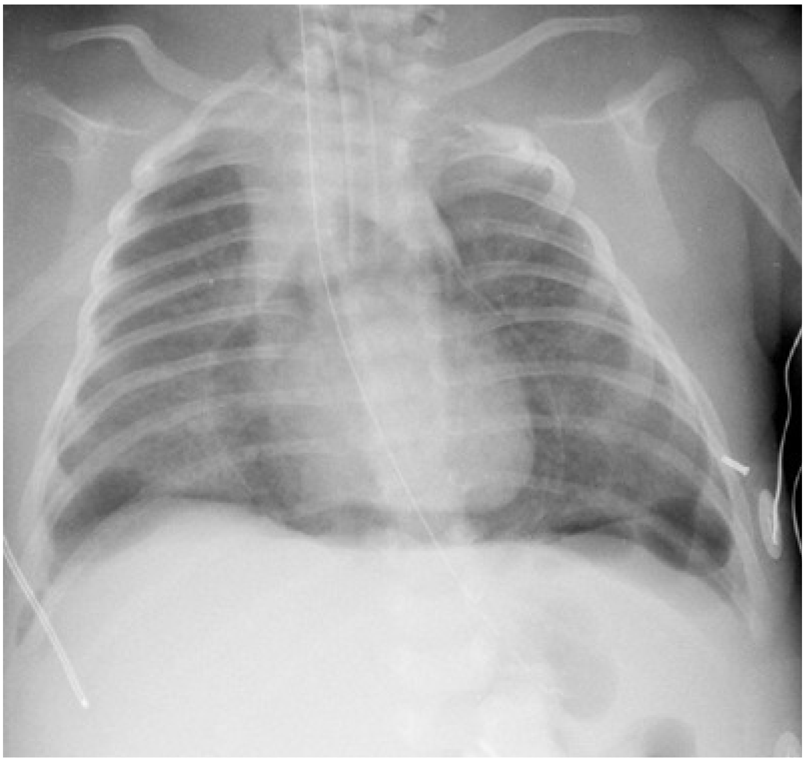


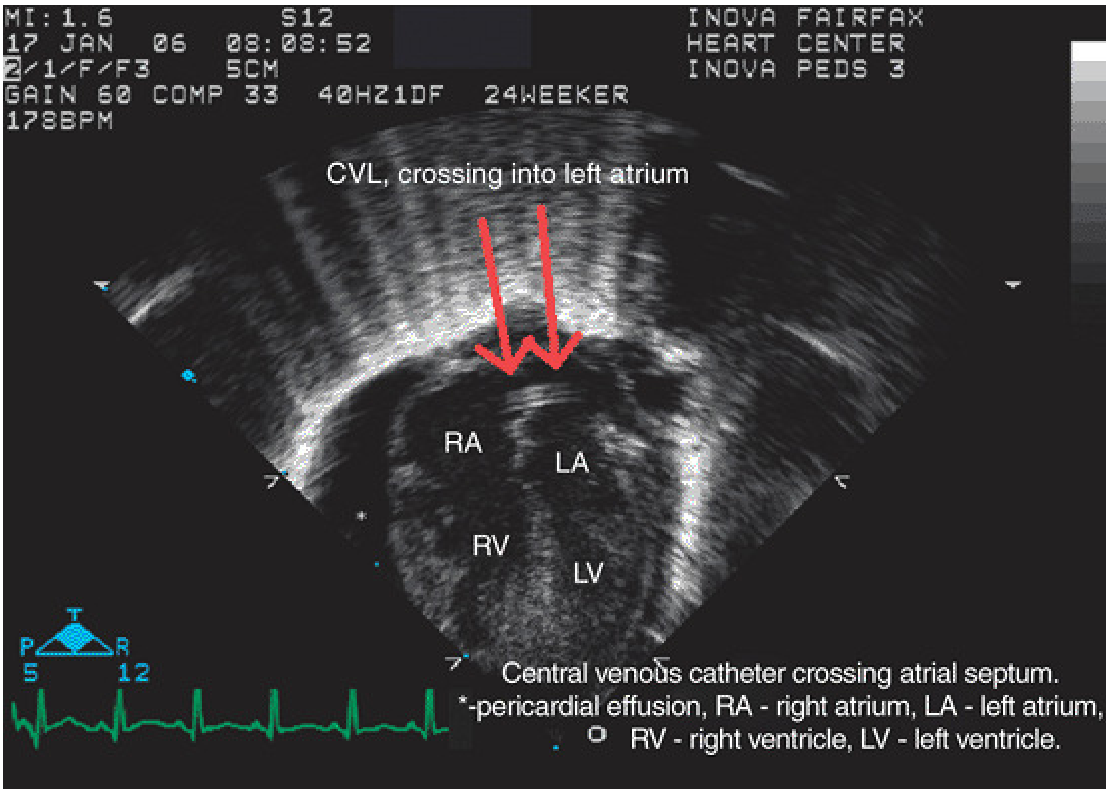
FIG. 37.2. Chest radiograph with pneumopericardium.

E. Contraindications

- There are no absolute contraindications to performing pericardiocentesis in the setting of cardiac tamponade.
- Relative contraindication for diagnostic pericardiocentesis
    - Coagulopathy
    - Active infection. (However, infection may also be an indication for diagnostic pericardiocentesis in some clinical situations.)

F. Limitations

- Cannot readily evacuate thrombus
- Cannot remove mass lesions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Central venous catheter crossing atrial septum.
*-pericardial effusion, RA - right atrium, LA - left atrium,
RV - right ventricle, LV - left ventricle.

FIG. 37.3. Echocardiogram image of preterm infant with pericardial effusion and central venous line in left atrium.

G. Equipment

- Antiseptic solution
- Sterile field with aperture drape or multiple drapes to be arranged around access site
- Sterile swabs or gauze pads
- Sterile gloves
- Local anesthetic, as needed
- 16- to 20-gauge intravenous cannula over 1- to 2-in needle
- Indwelling drainage catheter (optional)
- Three-way stopcock
- Short intravenous extension tubing (optional)
- 10- to 20-mL syringes
- Preassembled closed drainage system as for Emergency Evacuation of Air Leaks, Thoracostomy Tubes (optional)
- Connecting tubing and underwater seal for indwelling drain (optional)
- Transillumination device (optional, for pneumopericardium)
- Echocardiogram/sonography imaging device (optional in urgent situations)
- Specimen containers for laboratory studies, if procedure is diagnostic

H. Precautions

- Draining a large volume from the pericardial space can alter cardiac preloading conditions significantly, and some infants may require a supplemental intravascular fluid bolus after the pericardium is drained.

I. Techniques

- If ultrasound/echocardiographic imaging is available, and if time permits, then imaging can be performed to determine an optimal entry site and angle. In addition, the approximate distance required to reach the pericardial space can be estimated (15). Even after a sterile field is created, ultrasound imaging can be performed from a nonsterile area of the chest to monitor the effusion during the procedure. If imaging is done from a part of the sterile field, the transducer can be placed in a sterile sheath (or even a sterile glove), if needed. Care should be taken to avoid moving a probe with sterile cover back and forth between sterile and nonsterile areas.
- Similarly, evaluation with transillumination can be performed in cases of pneumopericardium, if time permits.
- Cleanse skin over xiphoid, precordium, and epigastric area with antiseptic. Allow to dry.
- Arrange sterile drapes, leaving the subxiphoid area exposed.
- Local anesthesia should be administered for the conscious patient. A typical example is 0.25 to 1.0 mL of subcutaneous 1% lidocaine instilled within 1 to 2 cm of the xiphoid process.
- Assemble the needle/cannula, three-way stopcock, and syringe so that the stopcock is open to both the needle and the syringe, but closed to the remaining port.
- The usual entry point in an infant is 0.5 to 1 cm below the tip of the xiphoid process, in the midline or slightly (0.5 cm) to the left of the midline. The needle should be elevated 30 to 40 degrees at the skin, and the tip should be directed toward the left shoulder (Fig. 37.4). A different approach may be used in certain cases, for example, if an echocardiogram suggests that most of the fluid is right-sided or apical.
- While advancing the needle, apply gentle negative pressure with the syringe. Continue advancing until air or fluid is obtained. If the syringe fills, use the third port of the stopcock to empty the syringe, or to attach a second syringe, and then aspirate more, repeating as needed. If diagnostic studies are desired, the fluid should be transferred to appropriate specimen containers.
    - If bloody fluid is aspirated, there could be a serosanguineous or hemorrhagic effusion, or the needle might have entered the heart (usually the right ventricle). There are a few clues that can be helpful in determining whether the needle has entered the heart; see J.

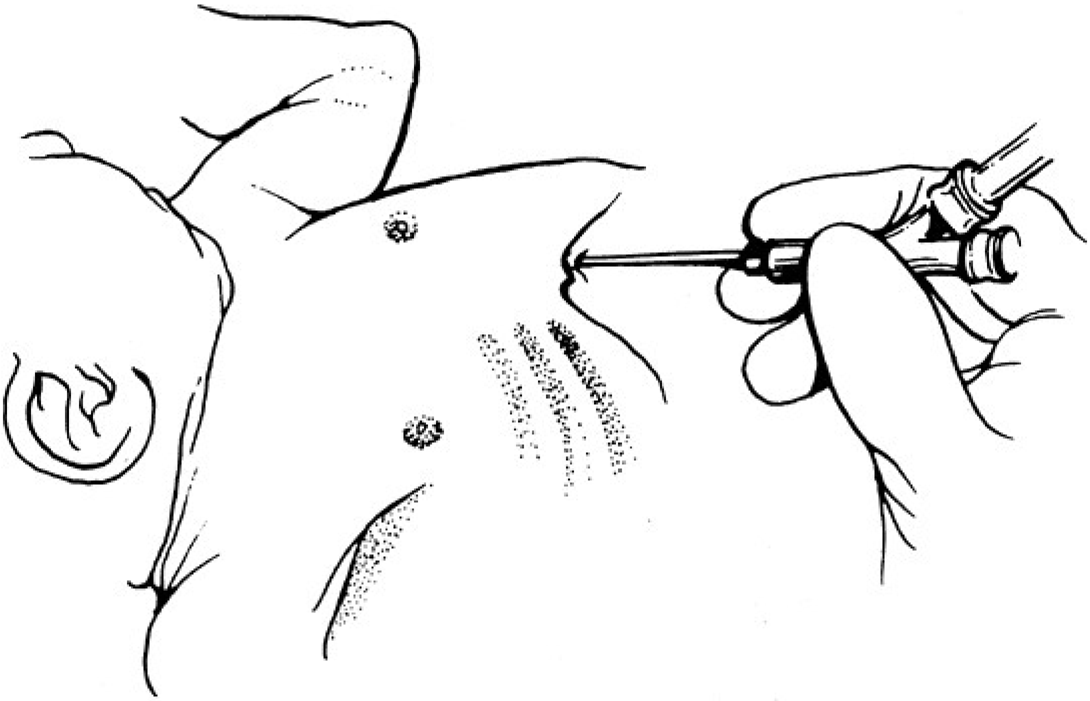

FIG. 37.4. Insertion of needle/cannula attached to three-way stopcock, in the subxiphoid space, directed toward the left shoulder.

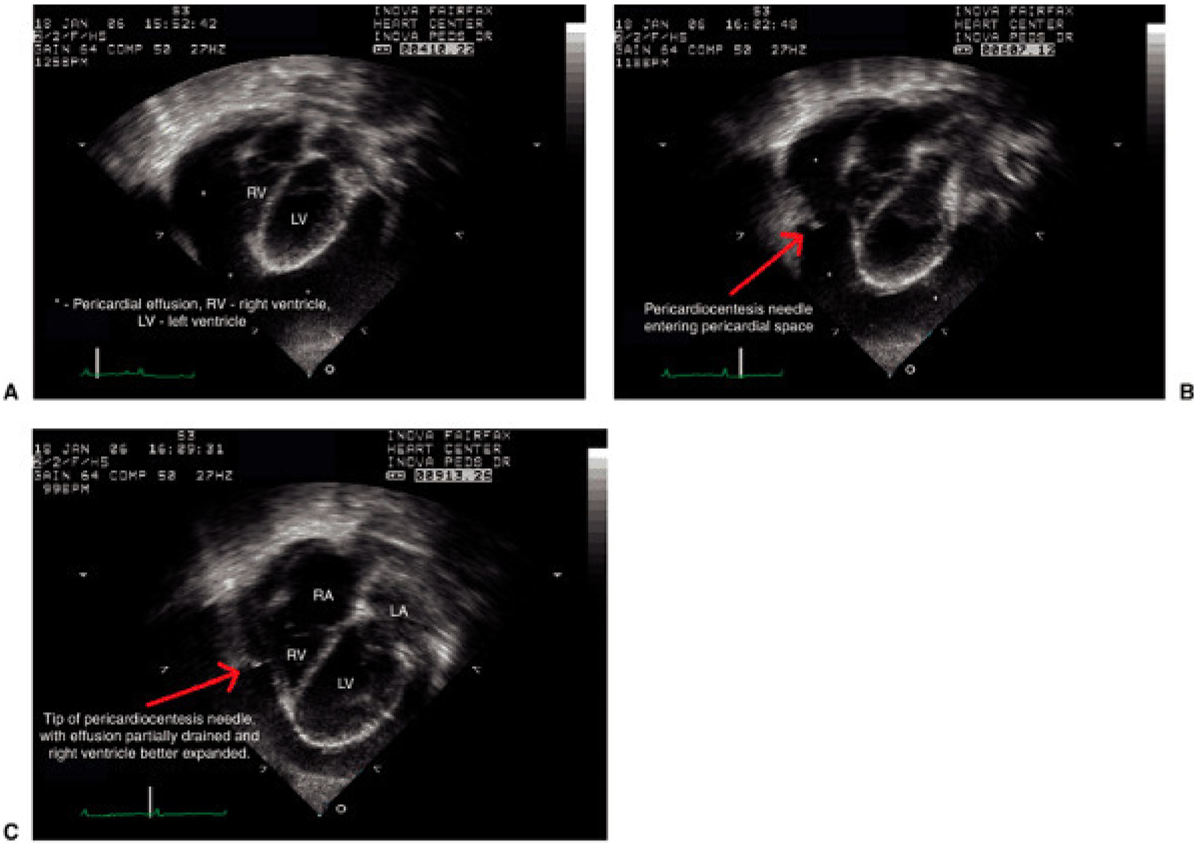
A
INOVA FAIRFAX
HEART CENTER
INOVA PEDS DR
18 JAN 06 15:52:42
GAIN 64 COMP 50 27HZ
RV
LV
* - Pericardial effusion, RV - right ventricle,
LV - left ventricle
B
INOVA FAIRFAX
HEART CENTER
INOVA PEDS DR
18 JAN 06 16:02:40
GAIN 64 COMP 50 27HZ
Pericardiocentesis needle
entering pericardial space
C
INOVA FAIRFAX
HEART CENTER
INOVA PEDS DR
18 JAN 06 16:09:21
GAIN 64 COMP 50 27HZ
RA
LA
RV
LV
Tip of pericardiocentesis needle,
with effusion partially drained and
right ventricle better expanded.

FIG. 37.5. Echocardiogram images of pericardiocentesis. A: Echocardiogram image of pericardial effusion. B: Tip of needle in pericardial space. C: Pericardial effusion partially drained.

  - A rhythmic tug, corresponding to the heart rate, may be felt as the needle enters the pericardium. Although this tugging sensation can reflect entering the myocardium, it can also be felt while the tip of the needle is positioned correctly within the pericardial space, and it does not necessarily mean that the needle has entered the heart.
  - If ultrasound imaging is available, needle position can be determined either by visualizing the tip of the needle within the pericardial space or by demonstrating that the amount of pericardial fluid is diminishing as fluid is aspirated (Fig. 37.5). Some authors have described reinfusing a small amount of the aspirated fluid while imaging, to observe the location of microcavitation echoes (15, 20, 21).
- Once the needle is in the pericardial space, as much pericardial fluid or air should be evacuated as possible. To accomplish this, fix the needle in position and advance the cannula over the needle into the pericardial space. Remove the needle, and connect the cannula to a closed system for aspiration, such as a three-way stopcock and a syringe. Aspirate as much fluid/air as possible.
  - Note that small single-lumen catheters may easily become blocked.
  - A decision will need to be made whether to leave the cannula in place for any length of time or to remove it once the pericardium has been drained. This decision will vary in individual cases, but factors to consider include the likelihood of reaccumulation and need for repeat drainage versus the risk of infection or entry of free air with an indwelling cannula.
  - In certain cases, the operator may elect to evacuate the pericardial space directly through the needle, rather than placing a cannula.

J. Special Circumstances

- If ultrasound imaging is available, it may be helpful in planning the needle entry site and angle, as well as anticipating the distance required to reach the pericardial space (2, 15, 17, 20, 21).
- If transillumination is positive for free air before the procedure, it can be used to assess the adequacy of air evacuation after the procedure, and to look for evidence of reaccumulation. Because pneumothorax and pneumomediastinum are potential complications, the availability of transillumination may also be helpful after the procedure. Transillumination is not reliable to rule out free air or to distinguish between pericardial air and mediastinal air (5, 6).
- Upon initial aspiration of the pericardium, one may encounter several different things: air, serous fluid, serosanguineous or grossly bloody fluid, or fluid resembling infusate from a central line, including parenteral nutrients and lipid solutions. One should not be startled by any of these. Bloody fluid raises the concern that the needle may have entered the heart. Several clues may be helpful in distinguishing between pericardial fluid and intracardiac blood.
    - In an infant with tamponade, aspirating 10 mL of blood from the heart will have minimal effect on the acute hemodynamics, whereas draining as little as 5 to 15 mL from the pericardial space can result in significant hemodynamic improvement within 30 seconds.
    - If ultrasound is being used, the pericardial fluid volume will appear to be decreased if the needle is correctly positioned. In some cases, one can reliably identify the needle in the pericardial space (Fig. 37.5) (15).
    - Placing a few drops on a clean gauze may help distinguish the two sources, because serosanguineous fluid will separate into a central dark red zone and a more serous peripheral zone, but this can take several minutes.
    - Alternatively, a spun hematocrit can be performed rapidly if the unit has a readily available centrifuge; this also takes a few minutes.
- Draining a large volume from the pericardial space can alter cardiac preloading conditions significantly, and some infants may benefit from intravascular fluid boluses after the pericardium is drained.
- Pericardiocentesis is often an urgent or emergency procedure. The technique for pericardiocentesis described above applies when there is time for each step. In an infant with significant hemodynamic compromise, the operator may be forced to omit certain steps in the interest of time. This requires a judgment as to the baby's clinical status and the time delay involved for any given step, such as waiting for the ultrasound machine, preparing a larger sterile field, or assembling a three-way stopcock system. In extreme cases, this life-saving procedure might consist of pouring or swabbing Betadine over the subxiphoid area, followed by â€œblindâ€□ aspiration using any available needle and syringe, without anesthetic, and before any other equipment is available at the bedside (15).

K. Complications (15, 16 and 17,20,21)

- Pneumopericardium
- Pneumomediastinum
- Pneumothorax
- Cardiac perforation
- Arrhythmia
- Hypotension (if a large effusion is drained)

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38-Gastric and Transpyloric Tubes

Allison M. Greenleaf

A. Definitions

- Enteral feeding is defined as providing nutrients distal to the oral cavity (1).
- gastric tube is a tube inserted via the nose or mouth to the stomach (2).
- transpyloric tube is a tube passed through the pylorus to the duodenum or jejunum (2).

B. Purpose (3)

- To provide a route for feeding
- To administer medications
- To sample gastric or intestinal contents
- To decompress and empty the stomach

C. Background

- Coordinated suck and swallow does not develop until after 32 weeks' gestation (2).
- In preterm infants, enteral feedings stimulate the secretion of hormones that influence development of the gastrointestinal (GI) tract.
- Early introduction of feedings is associated with improved bone growth, glucose tolerance, bile flow, and lower risk of nosocomial infection (4).
- Early enteral feeding leads to lower cost and decreased length of hospital stay.
- Incorrect placement of gastric and transpyloric tubes (incidence as high as 21% to 43%) can lead to substantial morbidity and mortality (5,6 and 7).

Oral or Nasal Gastric Tubes

A. Indications (3,8)

- Poorly coordinated suck and swallow
- Abnormal gag reflex
- Insufficient oral intake
- Respiratory symptoms that prevent oral feeding

B. Contraindications

- Recent esophageal repair or perforation

C. Limitations

- Size of nares
- Type and amount of respiratory support
- Congenital anomalies of the nasopharynx

D. Equipment

- Suction equipment
- Cardiac monitor

- Infant feeding tube
    - 3.5- or 5-French (Fr) feeding tube for infants weighing <1,000 g
    - 5- or 8-Fr infant feeding tube for infants weighing >1,000 g
- ½-in adhesive tape, pectin-based skin barrier
- Sterile water or saline
- 5- and 20-mL syringes
- Stethoscope
- Gloves
- pH paper

E. Precautions

- Measure and note appropriate length for insertion.
- Have suction apparatus readily available in case there is regurgitation.
- Do not push against any resistance. Perforation occurs even with very little force or sensation of resistance.
- Do not instill any material before verifying tube placement.
- Evaluate for possible esophageal perforation after insertion if there is:
    - Bloody aspirate
    - Increased oral secretion
    - Respiratory distress
    - Pneumothorax
- Stop the procedure immediately if there is any respiratory compromise.
- Ensure that the open tube drains below the level of the infant's stomach.

TABLE 38.1 Guidelines for Minimum Orogastric Tube Insertion Length to Provide Adequate Intragastric Positioning in Very Low-Birthweight Infants

Weight (g)	Insertion Length (cm)
<750	13
750-999	15
1,000-1,249	16
1,250-1,500	17

Data from **Gallaher KJ, Cashwell S, Hall V**, et al. Orogastric tube insertion length in very low birth weight infants. *J Perinatol.* 1993;13:128.

F. Special Circumstances

- Feeding with umbilical catheters in situ should be done with caution, as there are insufficient data to guide practice (4,9).
- Tubing should be vented between feedings if continuous positive airway pressure (CPAP) is in place.
- The pH of gastric secretions does not appear to be affected by the method of feeding (continuous versus bolus). Administration of acid-reducing medications such as H_2-receptor antagonists or proton-pump inhibitors does increase the pH of gastric secretions, but the pH is rarely >6 (6,10).

G. Technique

- Wash hands and put on gloves, maintaining aseptic technique.
- Clear infant's nose and oropharynx by gentle suctioning as necessary.
- Monitor infant's heart rate and observe for arrhythmia or respiratory distress throughout procedure.

- Position infant on back with head of bed elevated.
- Measure length for insertion by measuring distance from nose to ear to halfway between the xiphoid and umbilicus (4,6). Mark length on feeding tube with a loop of tape (Table 38.1) (11).
- Moisten end of tube with sterile water or saline.
- Oral insertion
    - Depress anterior portion of tongue with forefinger and stabilize head with free fingers.
    - Insert tube along finger to oropharynx.
- Nasal insertion (avoid this route in very low-birth-weight infants, in whom nasal tubes could cause periodic breathing and central apnea) (4).
    - Stabilize head. Elevate tip of nose to widen nostril.
    - Insert tip of tube, directing it toward occiput rather than toward vertex (Fig. 38.1).
    - Advance tube gently to oropharynx.
    - Observe for bradycardia.
- If possible, use pacifier to encourage sucking and swallowing.
- Tilt head forward slightly.
- Advance tube to predetermined depth.
    - Do not push against any resistance.
    - Stop procedure if there is onset of any respiratory distress, cough, struggling, apnea, bradycardia, or cyanosis.
- Determine location of tip. Injecting air to verify placement is not a reliable method, as the sound of air into the respiratory tract can be transmitted to the GI tract (4,6,12,13).
    - Aspirate any contents; describe and measure; determine acidity by pH paper.
        - Gastric contents may be clear, milky, tan, pale green, or blood-stained.
        - Gastric fluid pH should be <6 (5,6,10).
        - If the pH of the gastric aspirate is â‰¥6 or no aspirate is obtained, placement should be verified by radiography (5,14).
    - Suspect perforation or misplacement if no air or fluid is returned, or if there is onset of respiratory distress, blood in the tube, or difficult insertion.
- Secure indwelling tube to face with Â½-in tape. In preterm infants, apply the tape over a pectin-based barrier to prevent skin breakdown (15).
    - For feedings, attach to syringe.
    - For gravity drainage, attach specimen trap and position below level of stomach.
    - For decompression, a dual-lumen Replogle tube, connected to low continuous suction, is preferred.
- Pinch or close gastric tube during removal, to prevent emptying contents into pharynx.
- Document patient response, with any physiologic changes observed, and that tube placement was verified.

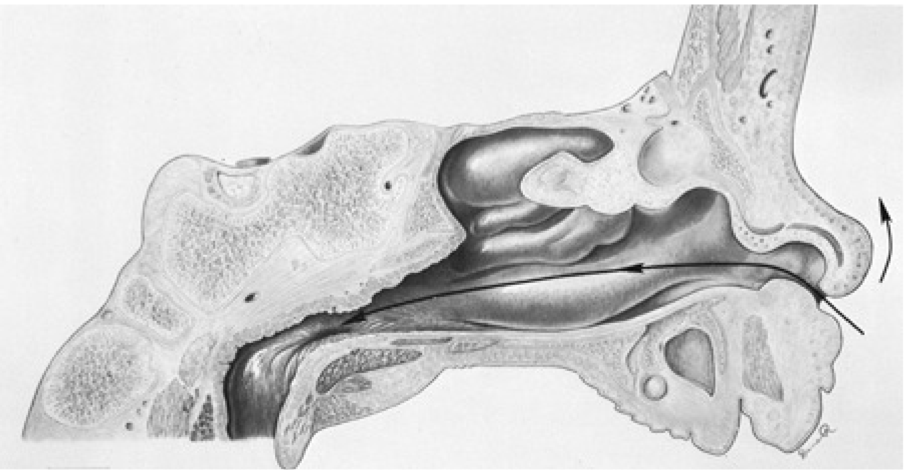

FIG. 38.1. Anatomic view of the neonatal nasopharynx. The natural direction in tube insertion is toward the nasal turbinates, where it might stop and give an impression of obstruction. By pushing the nostril up, one can direct a tube toward the occiput with less trauma.

H. Complications

- Apnea, bradycardia, or desaturation
- Obstruction of obligatory nasal airway
- Irritation and necrosis of nasal mucosa
  - Epistaxis
  - Ulceration
- Perforation (Figs. 38.2 and 38.3) (16,17 and 18)
  - Posterior pharynx, particularly at level of cricopharnyx
  - Esophagus
    - Submucosal, remaining within mediastinum
    - Complete into thorax
  - Stomach
  - Duodenum
- Misplacement on insertion (19)
  - Coiled in oropharynx (Fig. 38.4A)
  - Trachea (Fig. 38.4B)
  - Esophagus (Fig. 38.4Câ€“E)
  - Eustachian tube (20)
- Displacement after insertion because of inappropriate length or fixation
  - Pulling back into esophagus
  - Prolapsing into duodenum
- Coiling and clogging of tube
- Grooved palate with long-term use of indwelling tube (4)
- Increased gastroesophageal reflux
- Infection (4,21,22)

Transpyloric Feeding Tube

A. Indications

- Severe gastroesophageal reflux with risk of aspiration
- Gastric distention with continuous positive airway pressure
- Delayed gastric emptying

- Gastric motility disorders
- Sampling of duodenojejunal contents
- Intolerance to gastric feeds

B. Contraindications

- Clinical condition that compromises duodenojejunal integrity: necrotizing enterocolitis, fulminant sepsis, shock, patent ductus arteriosus, recent small-bowel surgery

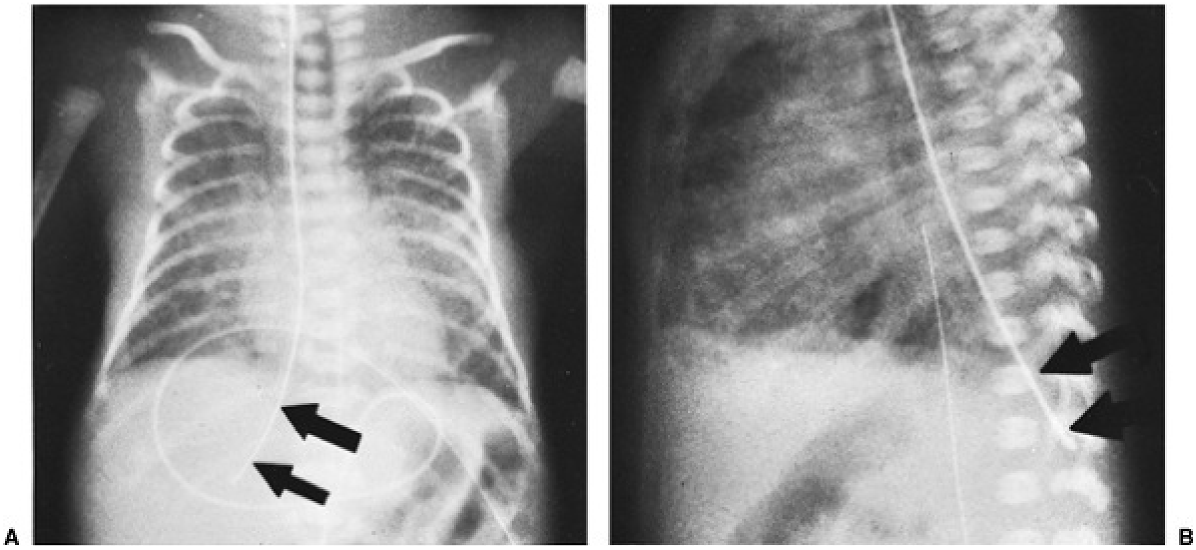

FIG. 38.2. Two radiographic views demonstrating a typical nasopharyngeal perforation with extrapleural malposition of a nasogastric tube at the right lung base (arrows). Either a traumatic endobronchial intubation or primary trauma from the nasogastric tube accounts for the perforation.

C. Limitations

- Long-term use may be associated with fat malabsorption, although recent studies suggest that there is no significant difference in growth over time (2,8).

D. Equipment

- Feeding tube
  - 3.5- or 5-Fr, 36-in silicone or Silastic tubes
  - Silastic tubes are preferred. Polyvinyl chloride tubes are not recommended for long-term use because the plasticizers are leached, stiffening the tube (4). â€œNonstiffeningâ€□ polyurethane tubes lose some of their compliance when left in place but stay softer for longer periods than polyvinyl chloride tubes.
- 20-mL syringes
- ½-in tape, pectin-based skin barrier
- pH paper
- Continuous-infusion pump and connecting tubing

E. Precautions

- When determining oral or nasal placement, individual assessment must be done to weigh the risks of compromising the nasal airway. Oral tubes are not at a significantly greater risk for dislodgement (23,24).

- Avoid pushing against any obstruction or resistance.
- Replace tubes as per manufacturer's recommendations. If the tube is stiff on removal, replace next tube sooner.
- If a tube has become partially dislodged, replace it rather than pushing it in farther.
- When using feedings that tend to coagulate in tubing, it may be necessary to flush the tube periodically with air or water.
- Use reliable infusion pumps that are safe for oral use by controlling rate and detecting obstructions.
- Limit infusion of hypertonic solutions and do not deliver bolus feedings beyond the pylorus.
- Consider the effect of continuous feedings on medication absorption.

F. Special Circumstances

- See oral or nasal gastric tubes, E.

G. Technique

- Insert orogastric tube as per gastric tubes above. Aspirate gastric contents.
- Measure distance from glabella to heels or from the nose to the ear to the xiphoid to the right lateral costal margin (14,25,26). Mark point with tape on transpyloric tube.

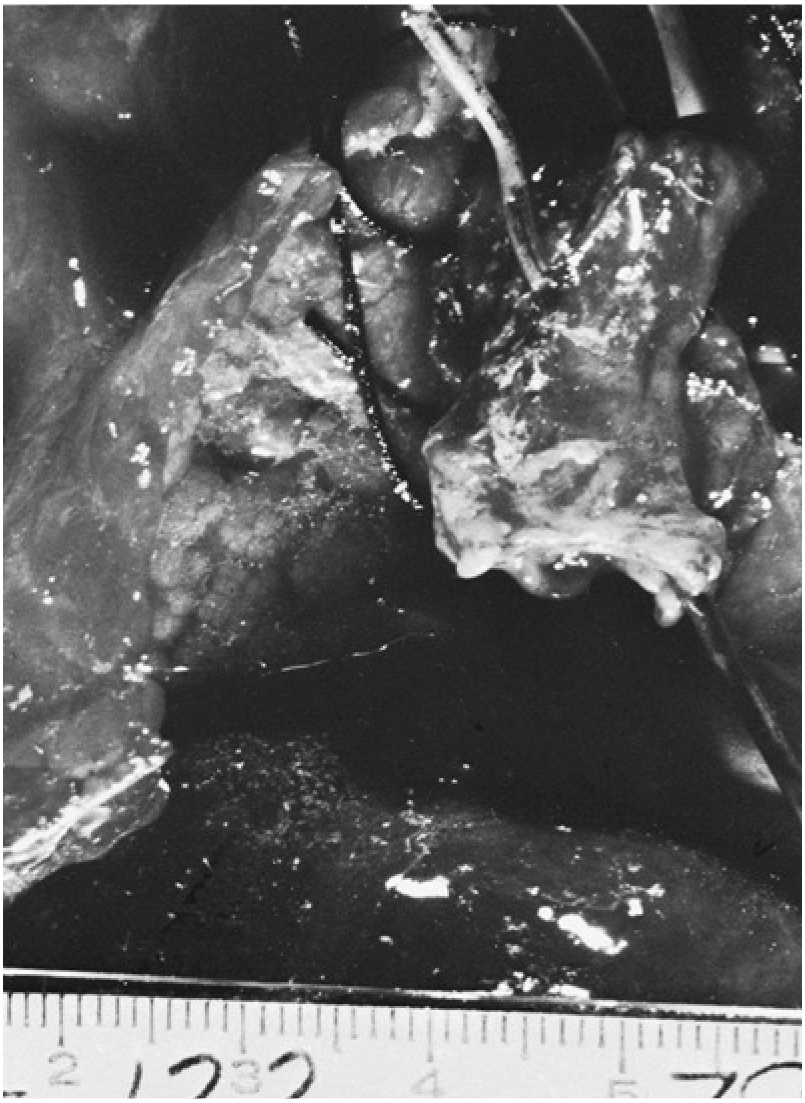

FIG. 38.3. Posterior perforation of the esophagus demonstrated in postmortem examination of 26-week gestational-age infant. Upper probe is through perforation. Barium from a premortem study

spilled through the perforation, causing pleuritis. Perforation may have occurred as a result of endotracheal intubation, suctioning, or passage of gastric tube and is more common in smaller premature infants.

- Turn patient onto right side and elevate the head of the bed 30 to 45 degrees (6).
- Inject 10 mL/kg of air through orogastric tube to distend stomach. Close orogastric tube (14,27).
- Pass transpyloric tube to predetermined depth.
- After approximately 10 minutes with infant remaining on right side, gently aspirate through transpyloric tube. Tube may be in position within duodenum if aspirate is
  - Without air
  - Alkaline
  - Bilious (gold or yellow in color)
- Verify placement by checking pH of aspirate. If pH is >6 and the color of the aspirate is gold or yellow, the tube is likely in place and radiographic confirmation is not necessary. If no aspirate is obtained or the pH is â‰¤6, placement should be verified via radiography (5,10,14,28,29). The tip of the tube should be just beyond the second portion of duodenum (Fig. 38.5).
- Data are emerging regarding the use of bedside bilirubin testing as an added verification of placement. Studies suggest that intestinal bilirubin â‰¥5 mg/dL confirms placement (6,10,28).
- Avoid pushing to advance tube after initial placement. If tube is not in far enough, retape to give external slack and to allow peristalsis to carry tip to new position.
- Most often, if the tube does not cross the pylorus within the first Â½ hour after passage, it is unlikely to pass in the next few hours, and it may be better to restart the procedure.
- After correct positioning, close transpyloric tube or start continuous infusion. Open gastric tube with syringe-barrel chimney or specimen trap to decompress stomach and to detect any transpyloric regurgitation.
- In larger infants, transpyloric tubes may be placed using a 6-Fr, unweighted, stylet-containing tube. This technique is not recommended for small infants.
- Transpyloric tubes may be placed with fluoroscopic guidance (6).

H. Complications (3) (See also Oral or Nasal Gastric Tubes, F)

- Misplacement into tracheobronchial tree, esophagus, or stomach, or incorrect position within proximal duodenum (19) (see Fig. 38.4).
  - Aspiration
  - Pneumonia

  The risk of aspiration with transpyloric feeding does not appear to be different from the risk with gastric feeding (8,24,30).

- Kinking or knotting of tube
- Hardening of polyvinyl chloride tube with leaching of bioavailable plasticizers
- Perforation of esophagus, stomach, duodenum (31,32)
- Perforation of kidney (33)
- Sepsis (21)
- Local infection (nasal colonization with staphylococci)
- Enterocolitis
  - Staphylococcus (21)
  - Necrotizing enterocolitis

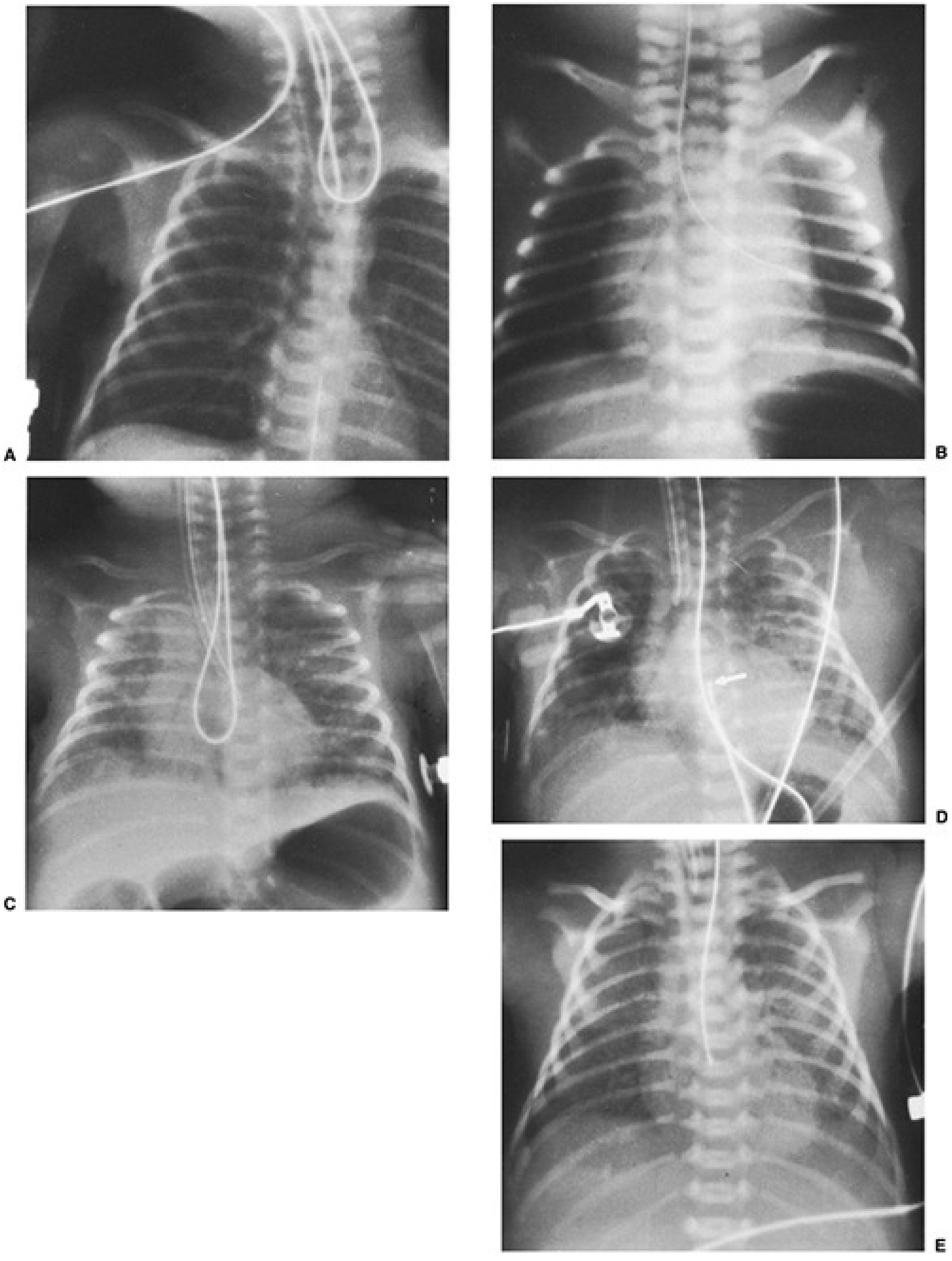

FIG. 38.4. Radiographic examples of misplaced feeding tubes. A: Tube coiled in the oropharynx and upper esophagus, simulating an esophageal atresia. B: Tube into the left mainstem bronchus. C: Tube coiled in the lower esophagus. D: Tube doubled on itself in the stomach with its distal end in the esophagus (arrow). E: Tube only into the esophagus. A rush may be heard on auscultation over the stomach when air is injected through a tube lying in this position, making that an unreliable sign of gastric location.

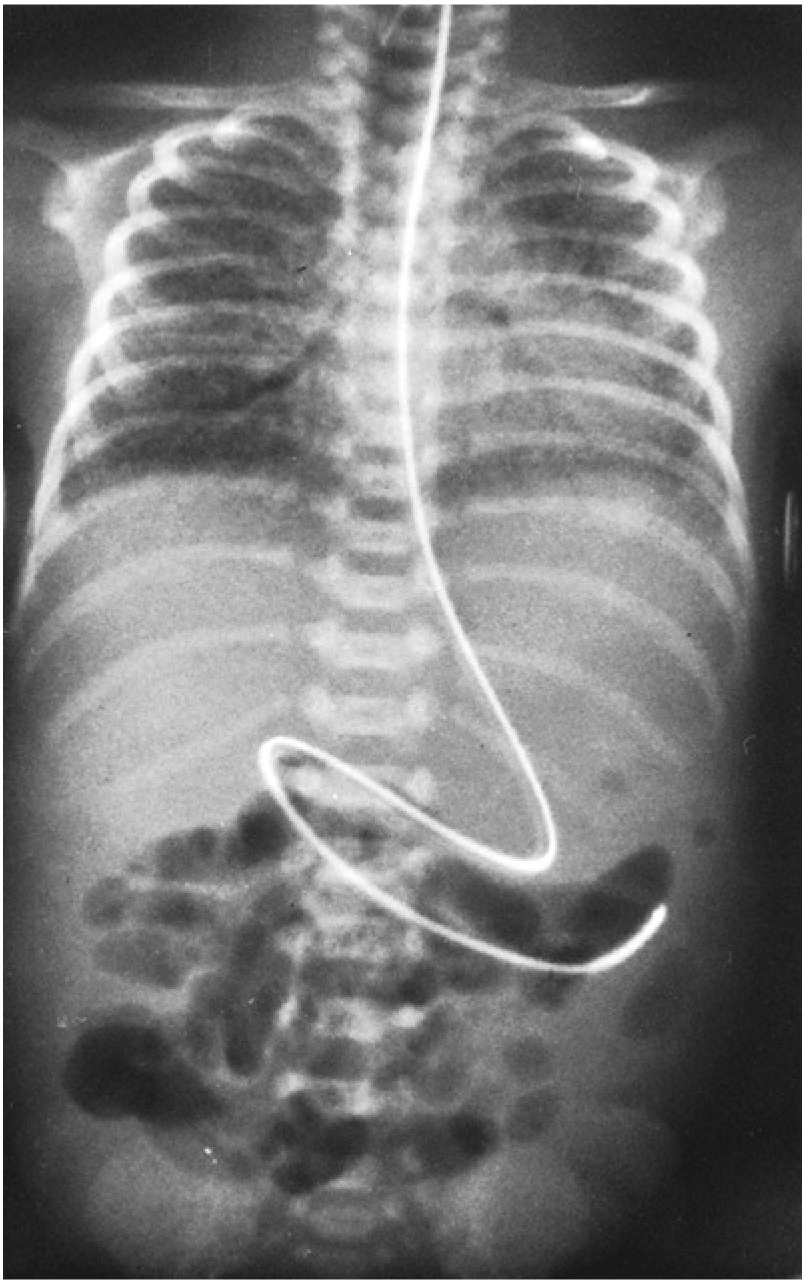

FIG. 38.5. Radiographic demonstration of a transpyloric feeding tube that has passed the ligament of Treitz, well below the more appropriate level, increasing the risk of perforation or nutritional dumping.

- Development of pyloric stenosis (34)
- Formation of enterocutaneous fistula (35)
- Interference with absorption of medications (36)
- Malabsorption and GI disturbance (2,4,5,8)
    - Fat malabsorption with nasojejunal feeds
    - Dumping syndrome if hypertonic medications or feedings instilled too rapidly
    - Gastrointestinal disturbance as characterized by abdominal distention, gastric bleeding, and bilious vomiting
- Intussusception (37)

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39-Gastrostomy

Thomas T. Sato

A. Indications

- Inability to swallow
    - Neurologic or neuromuscular deficit leading to uncoordinated oropharyngeal swallowing
    - Complex congenital malformations, including esophageal atresia or Pierre Robin sequence, not undergoing early correction
- Administration of supplemental feedings despite normal swallowing but inadequate oral intake
    - Chronic disease states
    - Requirement for unpalatable diet or need for consistent glucose source (i.e., glycogen storage disease)
- Presence of anatomic intestinal anomalies or functional intestinal dysmotility disorders that prevent normal enteral feeding
- Gastric decompression, particularly when respiratory compromise makes prolonged presence of nasogastric/ orogastric tube undesirable
    - Chronic gastrointestinal decompression: duodenal atresia, gastric volvulus, gastric gas/bloat from antireflux procedure

  - Emergency gastric decompression for inadequate mechanical ventilation secondary to gastric distention: tracheoesophageal fistula/esophageal atresia

B. Contraindications

The presence of treatable conditions that unduly increase operative risks, e.g., active infection or coagulopathy. These conditions should be treated aggressively prior to elective gastrostomy placement. Predictably, newborn infants with pure esophageal atresia or tracheoesophageal fistula with esophageal atresia have small stomach volumes (microgastria), making gastrostomy placement more difficult.

C. Equipment

Operative Insertion

- Sterile neonatal laparotomy instruments
- 12- to 14- French (Fr) mushroom (de Pezzar or Malecot) single-lumen catheters, 14-Fr Ross balloon-type gastrostomy catheters, or similar size latex-free Foley-type silastic catheters
- 3-0 or 4-0 absorbable sutures on taper needles
- Local infiltrative anesthesia (0.25% bupivicaine at 1 mL/kg bodyweight)

Maintenance Care after Insertion

- Fixation device
  - Modified feeding nipple, or
  - Cotton gauze bolster dressing
- Stomadhesive (Squibb, Princeton, NJ, USA)
- 3-0 or 4-0 permanent suture on cutting needle

D. Technique for Insertion

Neonatal gastrostomy placement often requires general anesthesia and frequently occurs as an adjunct to other abdominal operations. The technique varies according to individual surgeon preference, but the Stamm procedure described in 1894 is one of the most frequently used in premature infants and neonates (1). The gastrostomy should lie in the center of a triangle formed by the left costal margin, umbilicus, and xiphoid (Fig. 39.1).

Some data suggest that gastrostomy placement along the lesser curvature of the stomach may reduce the incidence of new-onset, postoperative gastroesophageal reflux (2,3). However, the small size of the neonatal stomach may make placement along the greater curvature more practical.

- After insertion of a nasogastric tube, sterile preparation of the skin, and delivery of intravenous antibiotics (typically a first-generation cephalosporin), enter the peritoneal cavity through either a transverse incision (Fig. 39.1) or a supraumbilical midline incision. Identify the stomach and elevate the anterolateral greater curvature of the stomach through the wound.
- Place two concentric, seromuscular purse-string sutures on the anterior greater curvature of the stomach body. Avoid injury to the gastroepiploic vessels (Fig. 39.2).
  - Inner purse-string for hemostasis
  - Outer purse-string for inversion of mucosa and fixing of stomach to abdominal wall

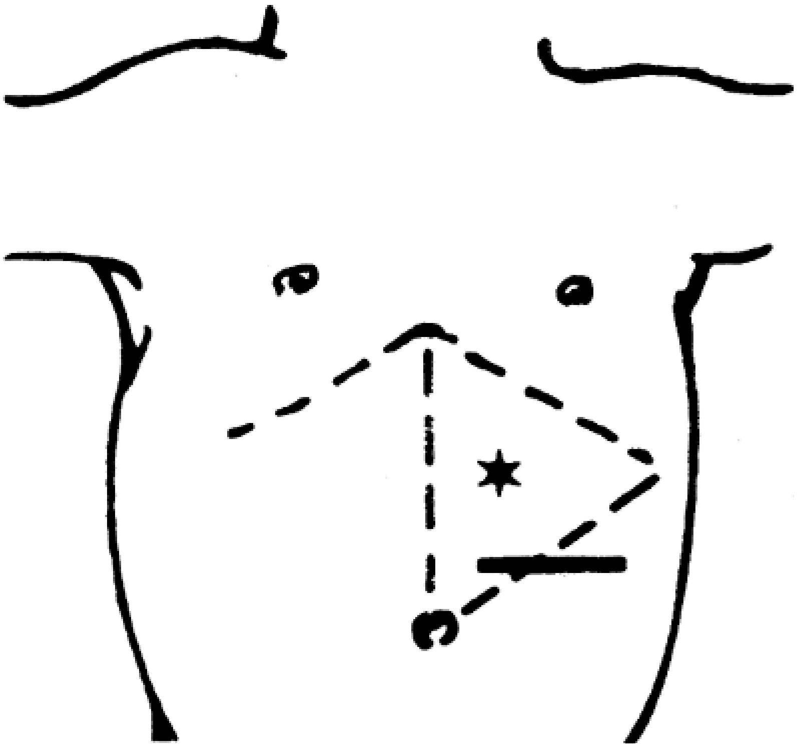

FIG. 39.1. Landmarks for gastrostomy. The primary horizontal incision is left supraumbilical. The gastrostomy tube will pass through the abdomen at a separate site in the center of a triangle formed by the xiphoid, umbilicus, and left costal margin.

- Make a stab wound through stomach wall (gastrotomy) in the center of purse-string sutures. With a stylet or grooved director inside the catheter, flatten the mushroom catheter head and introduce catheter through gastrotomy. Verify position of tube inside stomach.

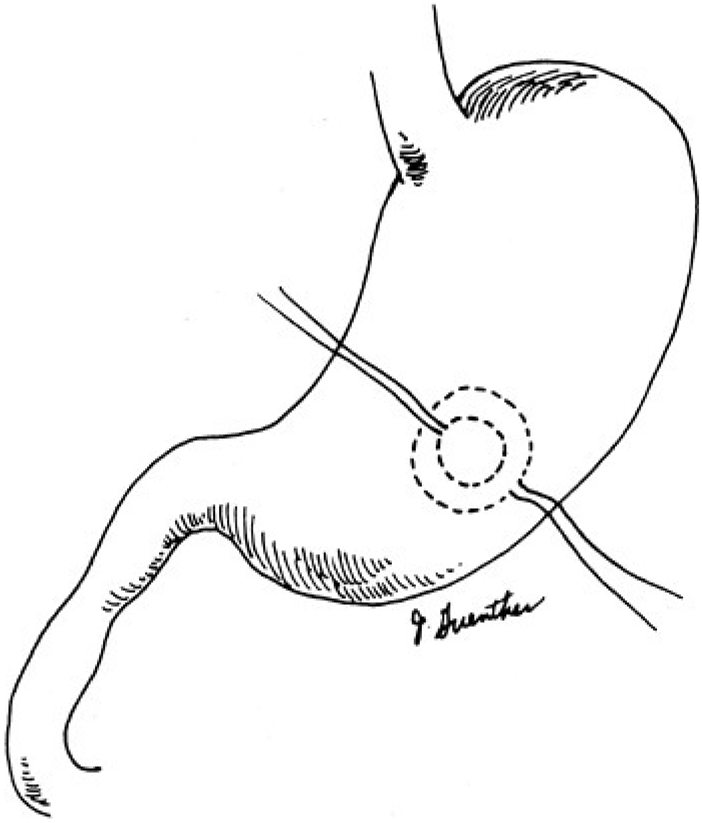

FIG. 39.2. Site for concentric sutures for Stamm procedure. Entrance into stomach is on greater curvature midway between esophagus and pylorus.

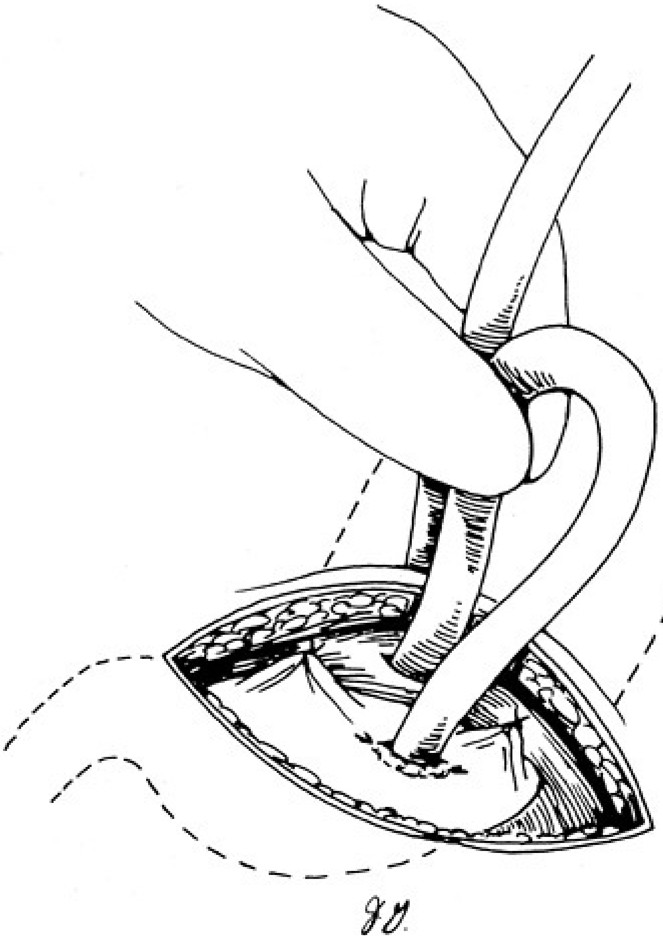

FIG. 39.3. After the tube is secured inside the stomach and passed through a stab wound in the

abdominal wall, the anterior wall of the stomach is sutured to the inner wall of the abdomen.

- Tie sutures sequentially. The inner purse-string suture secures the stomach around the catheter and provides hemostasis. The outer suture allows for inversion and water-tight seal of the stomach wall.
- At the identified exit site, make a stab wound through the abdominal wall (Fig. 39.1). A 3-mm dermal punch is often useful for this maneuver. Insert a curved hemostat through the abdominal wall exit site and expose the undersurface of the abdominal wall through the incision. Secure the stomach to the abdominal wall by placing three or four absorbable sutures through the gastric wall and the abdominal wall (Fig. 39.3).
- With a hemostat, pull the gastrostomy tube through the abdominal wall exit site until the stomach is snug against the abdominal wall. Tie the previously placed sutures while placing gentle traction on the gastrostomy tube (Fig. 39.3).
- Secure the gastrostomy tube to the skin with a suture to prevent inadvertent removal. Document the length of the gastrostomy tube outside the abdomen. Close the abdominal incision in routine fashion.

E. Fixation of Tube after Surgical Placement

Attention to gastrostomy tube fixation on the abdominal wall is critical to encourage proper gastrocutaneous tract formation and to prevent inadvertent removal or site irritation. The gastrostomy tube should be kept perpendicular to the abdominal wall to maintain the smallest possible orifice and to minimize leakage. A dressing that supports the gastrostomy tube in this position for 5 to 7 postoperative days is important. Once the dressing is removed and the wound healed, the gastrostomy tube may be secured to the abdominal wall with porous tape to avoid maceration of the skin.

Feedings may begin on the first postoperative day and increase as tolerated. Avoid clamping the gastrostomy tube with initial feedings. Use gravity suspension to prevent loss of gastric contents while allowing decompression of the stomach during drip feeding. Bolus gastrostomy feeding is generally started once the goal enteral feeding volume has been established using continuous drip.

Fixation of Gastrostomy to Abdominal Wall

- Catheter bridge (Fig. 39.4)
    - Either latex or nonlatex catheters may be used.
    - Cut a large, firm catheter at its wider end to a length of 3 to 4 cm.
    - Cut opposing holes at the midpoint of the catheter bridge just wide enough to admit but not constrict the gastrostomy tube.
    - Pull the gastrostomy tube through holes to create a tight seal on the catheter without constricting the lumen of the tube.

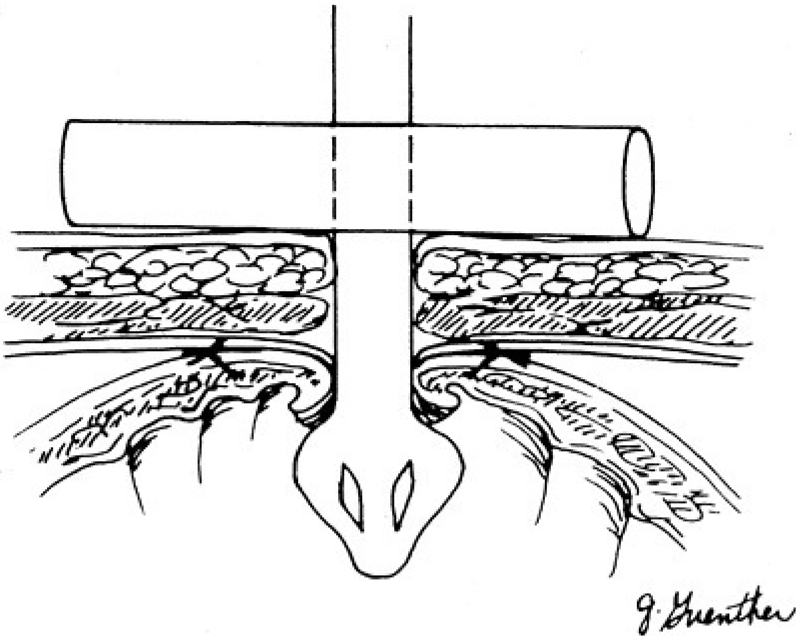

FIG. 39.4. Latex bridge at gastrostomy exit stabilizes tube perpendicular to skin, keeping stoma narrow to avoid leakage. Rotating the bridge around the tube allows change in contact points with the skin. Note how the flared end of the mushroom catheter is pulled to keep the stomach apposed to the abdominal wall.

  - Insert distal end of catheter into gastrostomy site as described above. If using a Foley catheter, inject 2 to 4 mL of saline into balloon.
  - Push catheter bridge snug against skin of abdominal wall.

  Pull Foley catheter balloon or mushroom catheter flange against the stomach and abdominal wall.

- Gauze Bolster Dressing
  - Fold gauze pad into bolster and use Steri-Strips or tape to affix bolster to abdominal wall next to the gastrostomy tube.
  - Loop the gastrostomy tube over the bolster, maintaining the gastrostomy tube perpendicular to the abdominal wall.
  - Secure gastrostomy tube to bolster and abdominal wall.
- Modified, soft, feeding nipple (4) (Fig. 39.5)
  - Because it is critical to keep the site as dry as possible, there must be modification of the nipple for good circulation of air.
  - Excise an elliptical window in flared base of nipple in circumferential direction 1 to 1.5 cm in length.
  - Make 1-cm crosscut in tip of nipple.
  - Slide nipple over gastrostomy tube until there is contact with abdominal wall.
  - Adjust tension on tube to pull gastrostomy balloon or flange against gastric wall.

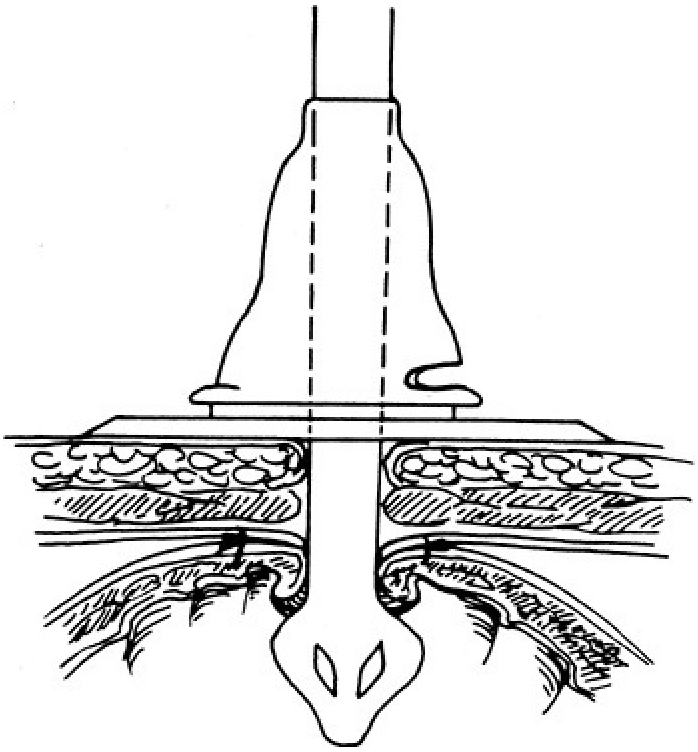

FIG. 39.5. Modified feeding nipple. The elliptical hole at the base allows air circulation and regular cleaning of the skin as important factors in avoiding maceration of the site. (From Kappell DA, Leape LL. A method of gastrostomy fixation. J Pediatr Surg. 1975;10:523, with permission.)

  - Tape or suture nipple flange to skin. Clean skin around gastrostomy with cotton applicators and keep area under nipple dry to avoid skin maceration.

F. Maintenance Care of Gastrostomy

- Maintain contact between stomach and abdominal wall.
  - Prevent gastric distention.
  - Keep gastrostomy balloon or flange pulled snugly against stomach wall.
  - Avoid pressure necrosis of abdominal wall (Fig. 39.4).
  - Avoid inadvertent dislodgement of gastrostomy.
- Keep tube immobile at insertion site to maintain stoma as small as possible.
  - Use careful fixation to maintain perpendicular position.

    Keep some slack in the tube when it is suspended.

- Prevent migration of tube through pylorus or esophagus by:
  - Proper fixation
  - Comparing length of external tube with postoperative length
  - Observing for signs of obstruction, for example,
    - Gastric distention, feeding intolerance
    - Increased drainage from oral gastric or gastrostomy tube
    - Bilious drainage
    - New-onset or increased gastroesophageal reflux

- Minimize leak from gastrostomy site in long-term gastrostomies.
    - Maintain adequate fit of tube in stoma.
    - Avoid local infection.
    - Treat leaking gastrostomy early.
        - Remove tube for 24 hours to allow partial closure.
        - Replace mushroom catheter with Foley catheter, and pull balloon (inflated with 2 to 5 mL H_2O) against abdominal wall to seal leak. Use catheter bridge or tape to secure tube.
        - Apply Stomahesive around catheter to decrease excoriation and to encourage epithelialization. Change Stomahesive every 3 to 4 days, as long as seal remains.
        - Maintain perpendicular position of gastrostomy tube.
        - Keep tube unclamped.
        - Maintain skin and stoma hygiene.
            - Cleanse daily with soap and water; â€œcrustyâ€□ exudate may be removed with half-strength hydrogen peroxide.
            - Keep area dry. Change dressing after cleansing skin and whenever wet.
    - Treatment of granulation tissue at gastrostomy site
        - Silver nitrate: Apply daily for 3 to 5 days.
        - 0.5% Triamcinolone ointment: Apply three times a day for 5 to 7 days.
        - Cautery: May require local or general anesthesia

G. Replacing Gastrostomy Tubes

- During the first 2 to 4 weeks after open gastrostomy placement, reoperation for replacement may be necessary.
- After formation of gastrocutaneous fistula, nonoperative placement is possible.
    - To avoid stoma closure, replace within 4 to 6 hours.
    - Use deflated Foley catheter for replacement prior to formation of well-epithelialized tract.
        - If the catheter does not pass easily, a flexible guidewire may be placed through the tract and confirmed in gastric position by fluoroscopy.
        - Lubricate catheter generously with water-soluble lubricant, and insert gently.
        - Inflate balloon with 2 to 4 mL of water, and pull against stomach wall.
        - Secure with fixation device.
        - Mark outside length of catheter to help detect internal or external migration of balloon.

          Prior to feeding, confirm placement of gastrostomy with water-soluble contrast study if replacement is difficult or uncertain.

    - For replacement, use mushroom catheter tube or balloon-type gastrostomy tube in well-established tract.
        - Carefully determine direction of tract.
        - Lubricate catheter.
        - Stretch tip of mushroom catheter with introducer.
        - Apply gentle pressure to insert catheter. Avoid force, which may lead to traumatic separation of stomach from abdominal wall.
    - Confirm intragastric position by one of the following methods.
        - For recent gastrostomy
            - Instill 15 to 30 mL of water-soluble contrast and obtain decubitus radiograph. Remove contrast.
        - For well-established gastrostomy, aspirate for gastric contents. If there is any doubt, obtain contrast study prior to initiating feeding.

H. Discontinuation of Gastrostomy Tube (5)

General

- Remove tube and apply gauze dressing.
- Allow spontaneous closure, usually 4 to 7 days, or
- Approximate skin edge with skin closure tape.

Persistent Gastrocutaneous Fistula

- Cause: Granulation and epithelialization of gastrocutaneous tract
  - Remove tube.
  - Cauterize granulation tissue or epithelium within stoma with silver nitrate sticks.
  - Seal orifice with Stomahesive.
  - Approximate edges with surgical tape.
- Persistent gastrocutaneous fistula of 4 to 6 weeks: Surgical closure required. If skin is becoming macerated, replace gastrostomy and use protective skin ointment prior to surgical closure.

I. Percutaneous Endoscopic Gastrostomy

The use of percutaneous endoscopic technique has become well established for primary gastrostomy tube placement in infants and children. There are several techniques, performed either with or without endoscopy.

- Percutaneous endoscopic gastrostomy (PEG)
  - â€œPullâ€□ technique (6)
  - â€œPushâ€□ technique (7)
  - â€œPokeâ€□ technique (8)
- Nonendoscopic (9)
- Currently available instrumentation and fiber-optic endoscopes allow for the safe performance of percutaneous gastrostomy in selected neonates, infants, and children. Placement typically requires general anesthesia for airway protection and control. The original method of PEG described by Gauderer in 1980 involves four basic elements:
  - Endoscopic gastric insufflation to approximate stomach to abdominal wall
  - Percutaneous placement of an introducer into the stomach under direct endoscopic visualization
  - Placement of a guidewire through the introducer and retrieval of the guidewire with an endoscopic snare; removal of the endoscope and the snared guidewire through the infant's mouth
  - Attachment of a gastrostomy tube to the guidewire and pulling it through the infant's oropharynx, esophagus, and into the stomach. The gastrostomy tube is modified with a tapered end where it is pulled through the abdominal wall and an intragastric mushroom-type flange to keep it from pulling completely out of the stomach (10).

    To provide prophylaxis against wound infection, a single intravenous dose of a first-generation cephalosporin or equivalent is recommended prior to PEG placement.

J. Laparoscopic Gastrostomy Placement

Placement of gastrostomy tubes in infants using a laparoscopic approach has been described as safe, efficacious, and may have a lower complication rate than percutaneous endoscopic gastrostomy (11). This approach allows direct visualization of the stomach via a 3- or 5-mm laparoscope.

- The laparoscope may be inserted either through the umbilicus or via a left upper quadrant incision at the proposed gastrostomy tube site.
- CO_2 insufflation to 8 to 10 torr is generally sufficient to visualize the peritoneal cavity.
- The stomach is directly visualized, grasped, and traction sutures placed to elevate the stomach to the abdominal wall; the gastrostomy tube is inserted into the stomach and the stomach is sutured to the abdominal wall.

K. Emergency Percutaneous Gastric Decompression

We describe an emergency percutaneous technique for gastric decompression that may be used as a life-saving measure when there is either respiratory failure or a high probability of gastric rupture in the presence of extreme gastric distention.

The primary indication for this type of procedure is for infants with massive abdominal distention causing respiratory failure that cannot be decompressed using an orogastric or nasogastric tube, for example, in infants with esophageal atresia and unrepaired tracheoesophageal fistula, requiring emergency transport to a definitive care facility:

- Prepare skin in upper left abdomen with Betadine.
- If possible, transilluminate abdomen to verify position of distended stomach away from liver.
- Make a small weal with 1% lidocaine to provide local anesthesia.
- Using a 20-gauge catheter with needle stylet, puncture the abdominal wall at the junction of the left anterior rib cage and the lateral border of the rectus abdominis muscle. Advance needle through wall into stomach.
- Remove needle and advance catheter into stomach. Attach short IV extension tubing, three-way stopcock, and syringe. Aspirate only enough air to relieve tamponade effect and improve ventilation. Avoid completely emptying stomach.
- Secure catheter and keep in place until surgical evaluation is possible.

L. Complications (10,12,13,14 and 15)

The complications associated with gastrostomy placement in the neonate may be characterized as either immediate or long-term (late). Most immediate complications are technical or mechanical in nature.
Immediate Complications (in approximate order of frequency)

- Pneumoperitoneum (after PEG)
- Wound infection, dehiscence, ventral hernia
- Prolonged ileus, gastric atony, feeding intolerance
- Separation of stomach from anterior abdominal wall
- Intraperitoneal spillage, gastric leak, peritonitis
- Injury to posterior wall of stomach on initial insertion or reinsertion
- Perforation or injury to other organs
    - Diaphragm
    - Esophagus (16)
    - Liver, spleen
    - Colon

Late Complications:

- Dislodgement
    - Inadvertent removal
    - Internal or external migration (17)
    - Intraperitoneal, extragastric placement

- Catheter deterioration
    - Catheter fracture
    - Balloon rupture
- Tube occlusion
- Persistent leak
    - Wound breakdown
        - Granulation tissue and skin irritation
        - Infection, particularly Candida
        - Loose gastrostomy with leakage
    - Electrolyte imbalance
    - Malnutrition
- New-onset or worsening gastroesophageal reflux disease (18)
- Persistent gastrocutaneous fistula following removal
- Adhesive bowel obstruction
- Prolapse of gastric mucosa
    - Bleeding
    - Excessive leakage
- Gastric torsion around catheter

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40-Neonatal Ostomy and Gastrostomy Care

Linda C. D'Angelo

An ostomy is the construction of a permanent or temporary opening in the intestine (enterostomy) or urinary tract (urostomy) through the abdominal wall to provide fecal or urinary diversion, decompression, or evacuation (1). Gastrostomies (G tubes) are stomas that allow direct access into the stomach and are used for feeding, medication administration, and decompression. This chapter discusses care of simple and complex ileostomies, colostomies, urostomies, and gastrostomies. Tracheostomy care is discussed in Chapter 35.

Enterostomies and Urostomies in the Neonate

A. Indications

Ostomies may be indicated in the neonate for a variety of congenital or acquired conditions (Table 40.1). The stoma is usually temporary, and reanastomosis of the bowel or urinary tract and closure of the stoma is performed during infancy or early childhood (2,3).

B. Types of Ostomies

- There are several types of intestinal stomas. The patient's condition, the segment of bowel affected, and the size of the patient's abdomen often determine the type of stoma and its external location. Figure 40.1 depicts the most common types of neonatal stomas (1).
- Urostomies are urinary diversions constructed to bypass a dysfunctional portion of the urinary tract. Ileal conduits and ureterostomies are rarely performed in the neonatal period.
- A vesicostomy is an opening directly from the bladder through the abdominal wall and is a more common urinary diversion in the neonate. Urine flows freely through the stoma from the bladder.

C. Ostomy Assessment

The neonate with a stoma needs careful observation and assessment for a variety of potential complications (4). Monitoring the infant for function of the ostomy is paramount in the initial postoperative period. Possible surgical complications are paralytic ileus, intestinal obstruction, anastomic leak, and stomal necrosis. The factors to be considered during evaluation of the stoma are listed below.

- Type of stoma: The segment of bowel from which the stoma is made.
- Viability: A healthy stoma should be bright pink to beefy red and moist, indicating adequate perfusion and hydration (Fig. 40.2). The stoma is formed from the intestine, which is very vascular and therefore may bleed slightly when touched or manipulated, but the bleeding usually resolves quickly. The stoma is not sensitive to touch because it does not have somatic afferent nerve endings (4).
    - A purple or dark brown to black stoma with loss of tissue turgor and dryness of the mucous membrane may indicate ischemia and possible stomal necrosis.
    - A pale pink stoma is indicative of anemia.
- Size: The stoma shape (round, oval, mushroom, or irregular) and diameter (length and width) in inches or millimeters is noted. In the early postoperative period, the stoma will be edematous. After

the first 48 to 72 hours, the edema should resolve and result in a reduction in size of the stoma, which should, however, still remain everted from the skin surface. Stomas generally continue to decrease in size over 6 to 8 weeks postoperatively. It is not uncommon for the stoma to become edematous when exposed to air while changing the pouch; this edema generally resolves quickly when the pouch is replaced.

- Stomal height: The degree of protrusion of stoma from the skin. Ideally, the surgeon will evert the stoma prior to suturing it to the skin to produce an elevation, which will promote a better seal with the ostomy wafer. With the stoma elevated above the surface of the skin, the effluent will be more likely to go into the pouch instead of staying in contact with the skin (2). Eversion of the stoma, referred to as maturing the stoma, is not always possible in neonates, in whom blood supply may be tenuous, and in situations in which the bowel is markedly edematous (1,5).

TABLE 40.1 Conditions Necessitating Ostomy in the Neonate

Disease/Congenital Anomaly	**Most Common Location of Stoma**
Intestinal atresia	Duodenum, ileum, or jejunum
Meconium ileus	Ileum
Necrotizing enterocolitis	Ileum or jejunum
Hirschsprung disease	Sigmoid colon
Imperforate anus/anorectal malformations	Colon
Volvulus	Ileum or jejunum
Bladder extrophy	Bladder

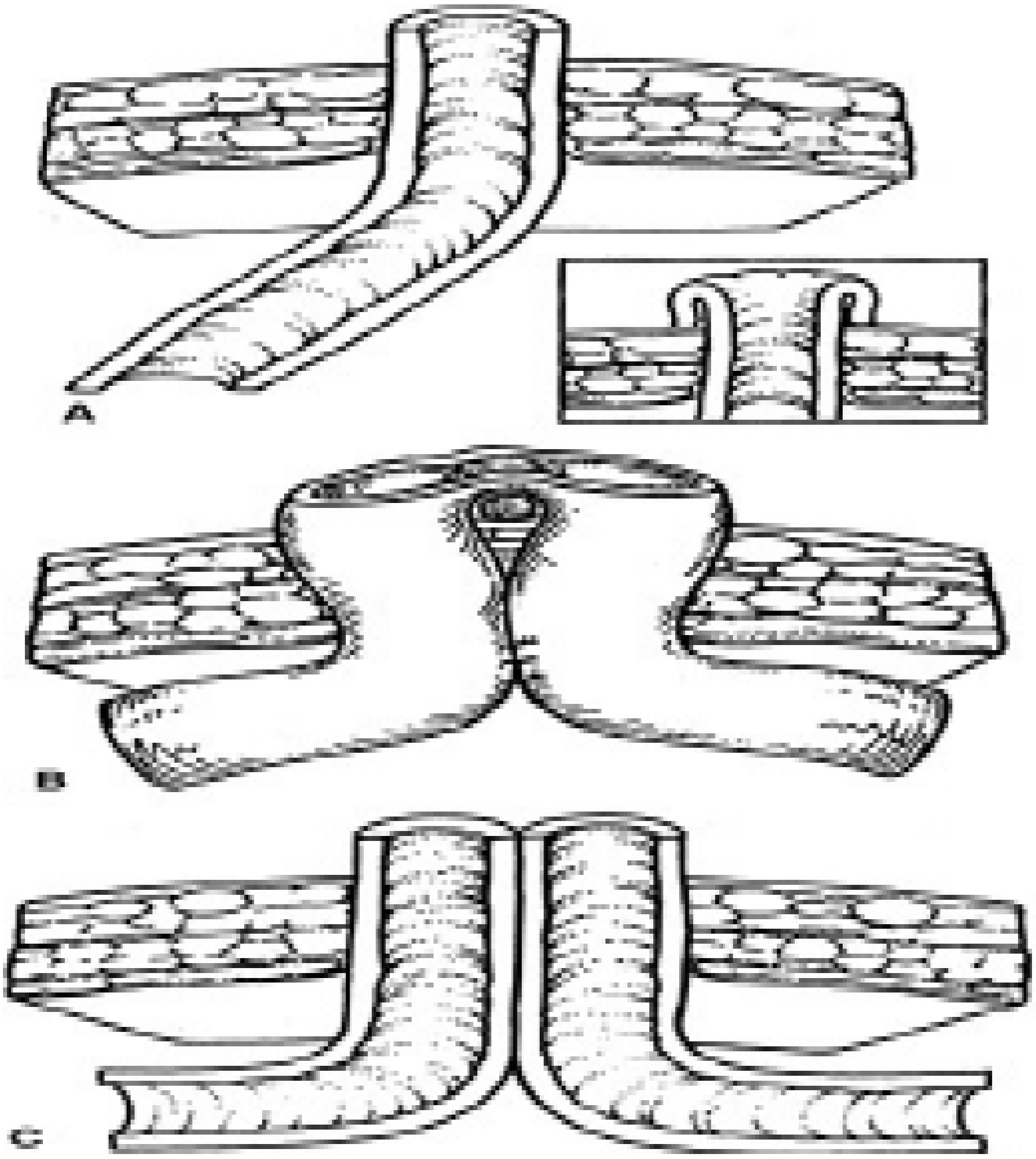

FIG. 40.1. A: End stoma. The end of the bowel is everted at the skin surface. B: Loop stoma. Entire loop of bowel is brought to the skin surface and opened to create a proximal, or functioning, end and a distal, or nonfunctioning, end. The distal side is called a mucus fistula because of the normal mucus secretions it produces. C: Double-barrel stoma. Similar to a loop stoma, except the bowel is divided into two stomas, a proximal and a distal stoma. The distal stoma functions as a mucus fistula. (Adapted from Gauderer MWL. Stomas of the small and large intestine. In: O'Neil JA, Rowe MI, Grosfeld JL, et al., eds. Pediatric Surgery. 5th ed. St. Louis, MO: Mosby; 1998:1349â€“1359, with permission.)

- Stomal construction: The ostomy may be an end, loop, or double-barrel (Figs. 40.1 and 40.3).
- Abdominal location
- Peristomal skin: Ideally the peristomal skin should be intact, nonerythematous, and free from rashes. However, frequently the stoma(s) is not separate from the surgical incision (Fig. 40.4). There is often not enough space on the baby's abdomen for the surgeon to create separate incisions. In addition, stomas are often in close proximity to the umbilicus, ribs, or groin, which may interfere with pouch selection and adherence (6).
- Stomal complications
  - Bleeding
    - Hemorrhage during the immediate postoperative period is caused by inadequate hemostasis (4).
    - Trauma to stoma caused by improper fitting pouch. A wafer cut too close to the stoma can injure the delicate tissue. Stomal lacerations can occur as a result of the edge of the wafer rubbing back and forth against the side of the stoma (4).
  - Necrosis: Caused by ischemia and may be superficial or deep. Necrosis extending below the facial level may lead to perforation and peritonitis, requiring additional surgical intervention (4).
  - Mucocutaneous separation: This condition is caused by a breakdown of the suture line securing the stoma to the surrounding skin, leaving an open wound next to the stoma.
  - Prolapse: Telescoping of the bowel out through the stoma. In infants this condition is frequently related to poorly developed fascial support or excessive intra-abdominal pressure caused by crying.
  - Retraction: The stoma is flush or recessed below the skin surface. This condition may result from insufficient mobilization of the mesentery or excessive tension on the suture line at the fascial layer, excessive scar formation, or premature removal of a support device (4).
  - Stenosis: The lumen of the ostomy narrows at either the cutaneous level or the fascial level. Sudden decrease in output may indicate stenosis.
- Peristomal complications
  - Dermatitis
    - Allergic dermatitis
    - Contact dermatitis: Most common type of peristomal skin complication seen, generally from the leakage of fecal effluent on the skin.
  - Infection
    - Bacterial
    - Candidal
  - Mechanical trauma: Epidermal stripping, abrasive cleansing techniques, or friction due to ill-fitting equipment are the most common causes of mechanical injury to the peristomal skin.
  - Hernia: A peristomal hernia appears as a bulge around the stoma that occurs when loops of the bowel protrude through a facial defect around the stoma into the subcutaneous tissue (4).

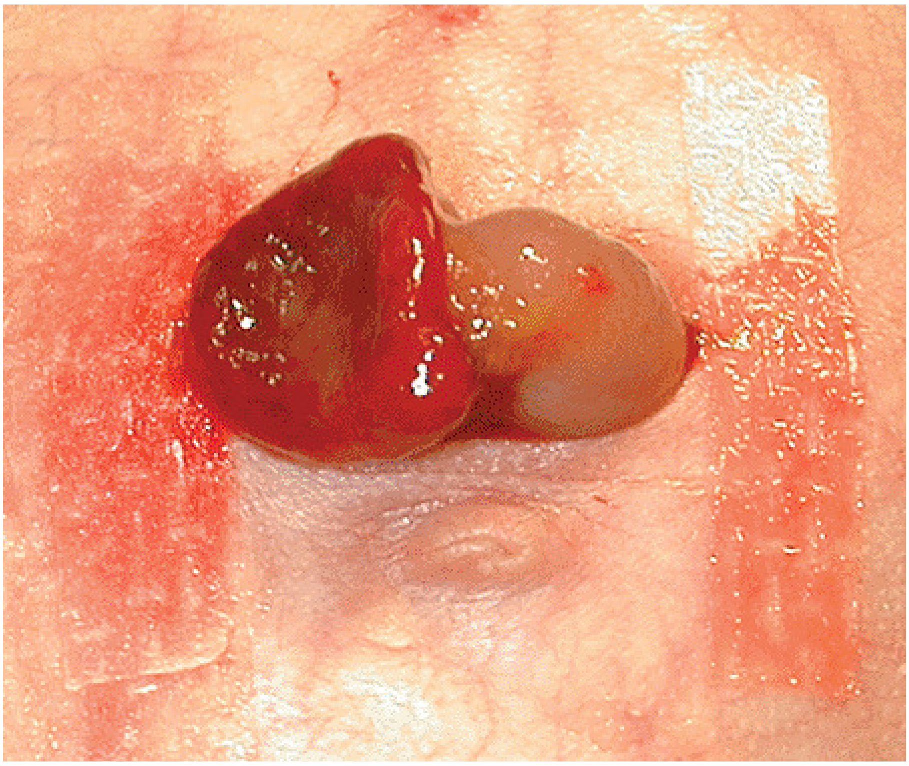

FIG. 40.2. Immediately postoperative loop ileostomy. Segment of bowel on left is the exteriorized perforation from necrotizing enterocolitis.

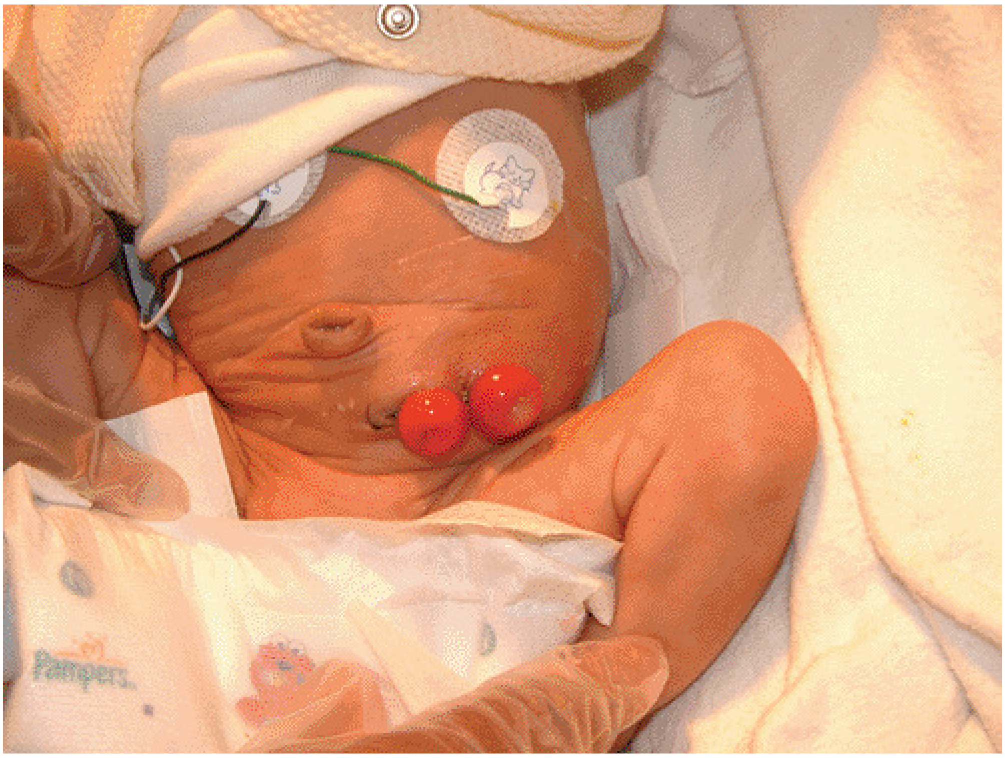

FIG. 40.3. Premature infant with double-barrel colostomy.

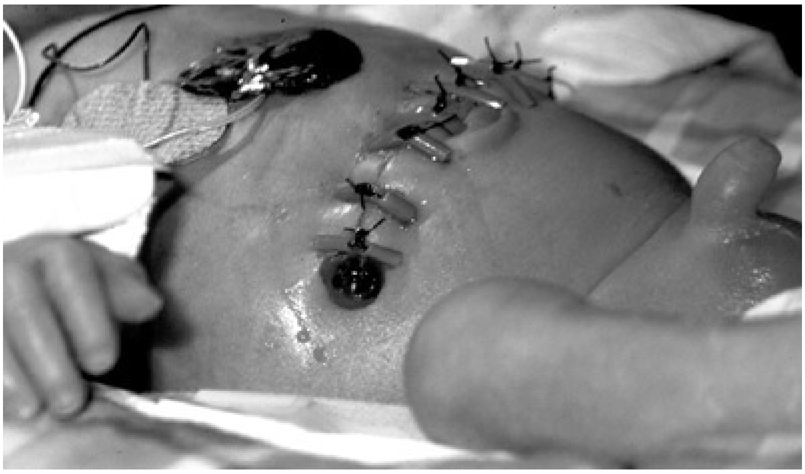

FIG. 40.4. End ileostomy and wound closure with retention sutures posing a challenge for placing a pouch.

D. Ostomy Care

- Immediate postoperative care
  - Assess stoma for adequate perfusion.
  - Protect the stoma. Although stool output is usually minimal in the initial postoperative period, covering the stoma with an ostomy pouch prevents the mucosa from drying out, especially if the baby is under a radiant warmer. Petrolatum gauze may be used in the postoperative period if placement of the pouch has to be delayed because of problems with skin integrity.
  - Cover the mucus fistula with a moisture-retentive dressing to keep it from drying out. When securing a dressing on a neonate, use low-tack adhesives. There is increased risk of skin tears in neonates, especially when they are premature with delayed epidermal barrier development. Avoid placing petrolatum gauze over the pouching surface for the stoma, as it can impede adherence.
- Subsequent care
  - Regular assessment of the stoma
  - Protect peristomal skin from the effects of the effluent by pouching (Fig. 40.5). The effluent from a small bowel stoma contains proteolytic enzymes that can rapidly cause skin erosion. Ideally the bag should remain in place for at least 24 to 72 hours. The bag must be changed if there is any evidence of leaking effluent under the skin barrier wafer. Frequent bag changes, however, can result in denuded skin, especially in the premature infant (2,4,7). In situations with frequent leaking and pouch changes, expert help may be required to preserve the skin and obtain acceptable wear time. When a pouch cannot be maintained, it may be necessary to leave the pouch off and protect the peristomal skin with a protective barrier paste that will adhere to denuded skin to allow the skin to heal. The barrier ointment can be covered with petrolatum-impregnated gauze; fluff gauze can then be placed on top to absorb the effluent and changed as needed. In some cases of severe skin damage, some neonatal centers stop enteral feedings briefly to limit stool production and allow the skin to heal (2).
  - Protect stoma from trauma. Measures include accurate sizing of the opening to clear the stoma as the size changes. If the infant's movements cause the inner edge of the barrier to rub against the stoma, a moldable barrier between the stoma and the wafer can be used to protect the stoma.

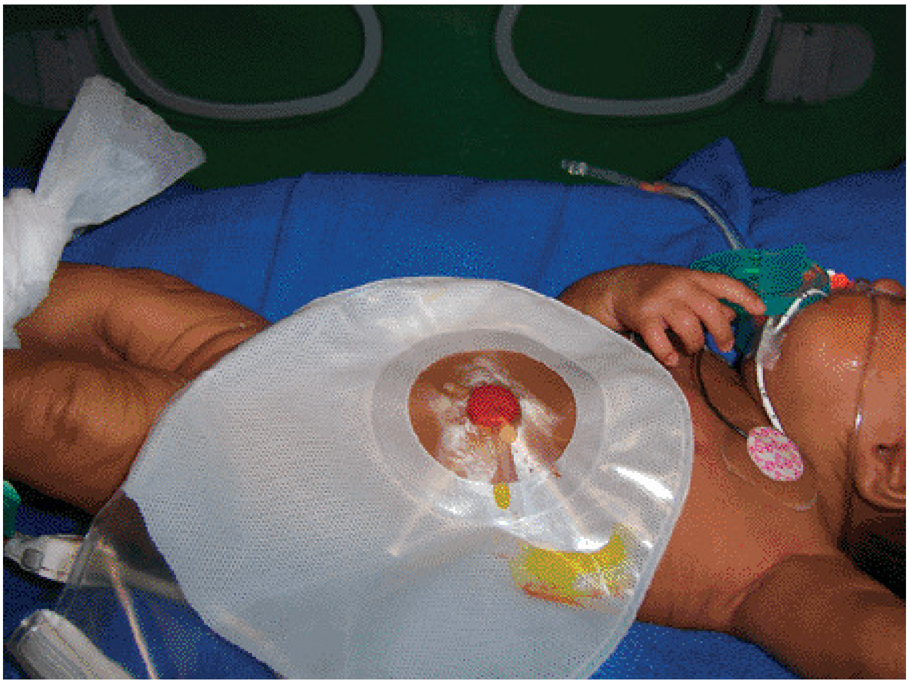

FIG 40.5. One-piece ostomy appliance on small newborn dwarfs this infant, but provides longer wear time and holds larger volume of output than the preemie pouches previously used.

E. Equipment

Several different types of pouches and ostomy care supplies are available (Tables 40.2 and 40.3). One-piece pouches come with a barrier and pouch attached as a single unit. Two-piece appliances have a barrier and pouch separate, with a mechanism for attaching the pouch to the wafer, generally in the form of a plastic flange that snaps together. The type of pouch used with a neonate is generally either an open-end pouch that allows the passage of thick or formed effluent or a urostomy pouch with a spout designed for drainage of urine or liquid effluent. The type of pouch and the need for accessory products varies depending on the size of the child, the condition of the peristomal skin, abdominal size and contours, and institutional preference. In general, it is best to keep the procedure simple and to use as few products as possible (2). Special consideration needs to be given to the premature infant whose skin is immature and fragile. Several companies manufacture pouches for neonates and premature infants (Fig. 40.7). Neonatal units should have several varieties to choose from in order to meet each patient's individual needs.

Supplies

- Clean gloves
- Warm water
- Small basin or tub
- Clean, soft cloth
- 2 x 2-in gauze
- Appropriate-size pouch with clip/closure device
- Protective skin barrier wafer (if not using one-piece pouch)
- Other ostomy accessories as appropriate (Table 40.3 and Fig. 40.8).
- Scissors or seam ripper
- Stoma-measuring device

F. Applying the Pouch: Routine/Simple Ostomies (2,6,8)

- Remove old pouch by gently pulling up the edges and using water to loosen while pressing down gently on the skin close to the edge to reduce traction on the epidermis. Adhesive remover should not be used on a neonate <2 weeks of age. Limited use of adhesive remover, followed by thorough cleansing of the area to remove any chemical residue, is recommended only when the adhesive bond of the barrier to the skin is so strong that the skin might be injured during removal (2).
- Use damp soft gauze or paper washcloth to gently cleanse the stoma to remove adherent stool or mucus. It is common to have a little bleeding of the stoma when it is cleansed.
- Wash peristomal skin with water; pat dry. Soap is not recommended because it may leave a chemical residue that could cause dermatitis; furthermore, many soaps contain moisturizers that can adversely affect the adherence of the barrier to the skin. It is also not advisable to use commercial infant wipes, because most are lanolin-based and contain alcohol (2).
- Measure stoma(s) using stoma measuring device (Fig. 40.9). The opening generally is cut $^{1}/_{16}$ to 1/8 in larger than the stoma, to limit the skin exposed to effluent. In tiny infants, in which the mucus fistula may be immediately adjacent to the functional stoma, one pouch may be sized to fit over both the stoma and the mucus fistula.

TABLE 40.2 Ostomy Pouches

Type	**Advantages**	**Disadvantages**
One piece (wafer and pouch combined as one unit)	Simple and easy to apply Good choice for simple stomas	Difficult to customize, especially with multiple stomas or abdominal irregularities Sometimes too large for small, premature infants
Two piece (wafer and pouch separate)	Easier to customize, especially for multiple stomas, abdominal irregularities	More time-consuming to prepare More products to keep track of
Cut to fit with starter hole (may be either one-piece or twopiece type pouch)	Can be adjusted to meet changing stoma size, assuming starter hole is not larger than stoma size	Must be sized and cut with each pouch change
Cut to fit without starter hole (may be either one-piece or two-piece type pouch)	Can be adjusted to meet changing stoma size Can be customized to fit difficult stomas, multiple stomas, or to place stoma off-center in bag	Must be sized and cut with each pouch change Difficult to start hole; must be careful not to poke through bag with scissors
Precut hole (may be either onepiece or two-piece type pouch)	If stoma size is stable, less cutting and adjusting needed with each bag change Recommended for home use in older patients in whom stoma size will not change frequently	Stoma size may change and bag will not fit properly Difficult to stock large variety of custom sizes to meet needs of all NICU patients Not recommended for NICU stock
Pouch choice of open-end, urostomy, or closed-end	Open end allows any type of effluent to pass through. Urostomy allows liquid effluent to pass in a more controlled manner. Closed end will not leak inadvertently from clip or closure failure.	Closure device may not hold for open-end pouch. Tail of pouch is more difficult to keep clean. Very thick liquid may not pass through the urostomy port, but can be thinned by instilling water first. Closed-end pouch must be removed to empty.

NICU, neonatal intensive care unit.

- Trace hole size onto wafer. Cut hole(s) using small scissors or a seam ripper (Fig. 40.10). After cutting, and before removing the paper backing, check the fit around the stoma and trim more if needed. Run a finger along the inside of the opening to make sure there are no sharp edges; these can be cut or smoothed by rubbing with the finger. It may be necessary to trim the wafer to avoid umbilicus, groin, etc. Cutting small slits along the edges of the wafer may help the barrier conform to the contour of the stomach.
- Warm wafer in hands to promote flexibility and enhance bonding to the skin. Avoid using a radiant heater to heat the wafer, because the amount of heat absorbed cannot be controlled and may burn immature skin (2).
- Press wafer to skin and hold for 1 to 2 minutes. Secure the edges of the wafer down to the skin to improve wear time. Avoid the use of high-tack adhesives. Pink tape is a waterproof tape that contains zinc oxide; it is very gentle and generally can be used safely. Other low-tack alternatives are paper tape, silicon tape, or clear film dressing.
- Change dressing to mucus fistula using a folded 2 x 2-in gauze piece and low-tack adhesive, or secure with diaper or tubular elastic dressing.

TABLE 40.3 Ostomy Accessory Products

Product	**Indications and Precautions**
Barrier powder	This product is used to dry moist and/or weepy skin. It can add extra adhesiveness to the skin. It must be sealed by padding with a moistened finger and allowed to dry. In cases of severely moist weeping skin, it may be necessary to apply powder and seal two or three times to attain a dry peristomal skin surface. It adds an additional barrier over the skin to protect from drainage. Apply in limited amounts and wipe off excess. Protect infant from inhalation of aerosolized powder by using minimal amounts and wiping away gently; do not blow powder away.
Paste	Barrier product that is semiliquid because of addition of alcohol. Best if applied to barrier and allow to air for 1 to 2 minutes to allow the alcohol to evaporate (Fig. 40.6). Not recommended for use on premature infants or term infants <2 weeks old.
Skin sealants	Sealants use plasticizing agents to form a barrier on the skin that can protect from effluent and also improve adherence of some adhesives. Most skin sealants contain alcohol and are therefore contraindicated for use in preemies or term neonates <2 weeks old. One skin sealant that does not contain alcohol is Cavilon No Sting Barrier Film (3M, St. Paul, MN, USA).
Moldable barrier	Barriers that are adhesive and can be shaped to fill in uneven spaces; generally hold up very well to corrosive effluent. Common types are Eakins Seals (Convatec, Princton, NJ, USA), and Barrier No. 54 (Nu-Hope Laboratories, Pacoma, CA, USA)
Caulking strips	Similar to moldable barriers, but come in narrow strips; they can be used to provide an extra barrier between the edge of the stoma and the barrier. May come in contact with stoma; soft enough that it does not injure the mucosa. Examples are Ostomy Strip Paste (Coloplast, Marietta, GA, USA) and Skin Barrier Caulking Strips (Nu-Hope Laboratories, Pacoma, CA, USA).
Belt	Elastic belt with tabs that fit to ostomy pouch of some two-piece appliances. Belt can help maintain the appliance in place by holding it firmly to abdomen. Generally used as a last resort when unable to obtain acceptable wear time.

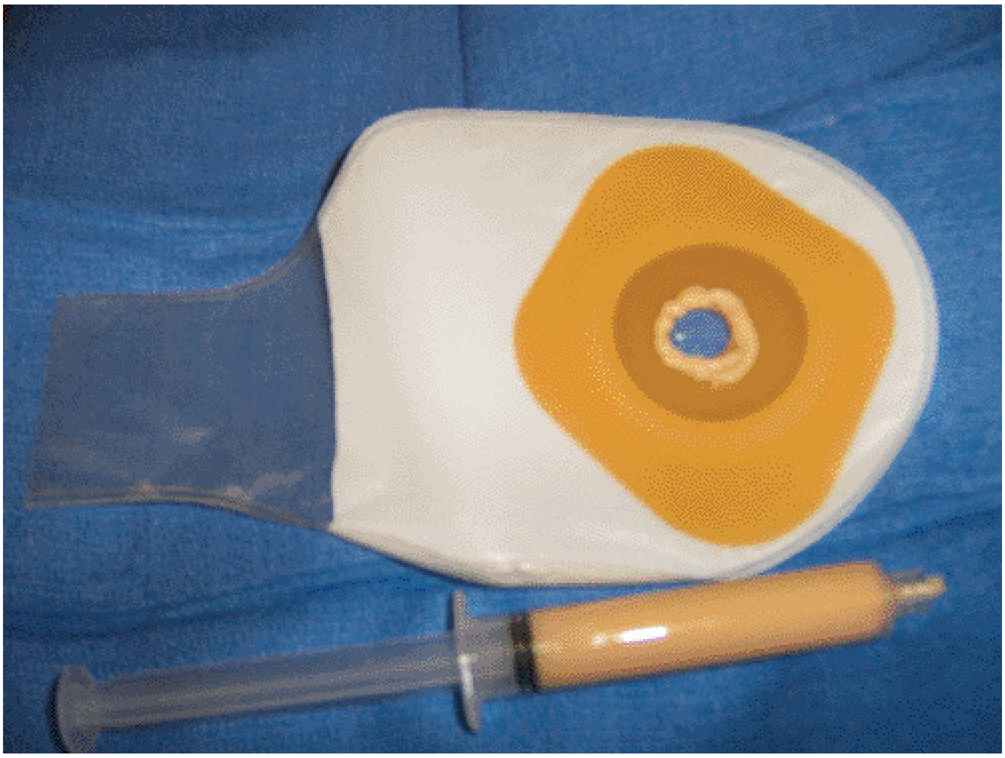

FIG 40.6. Barrier paste applied to wafer.

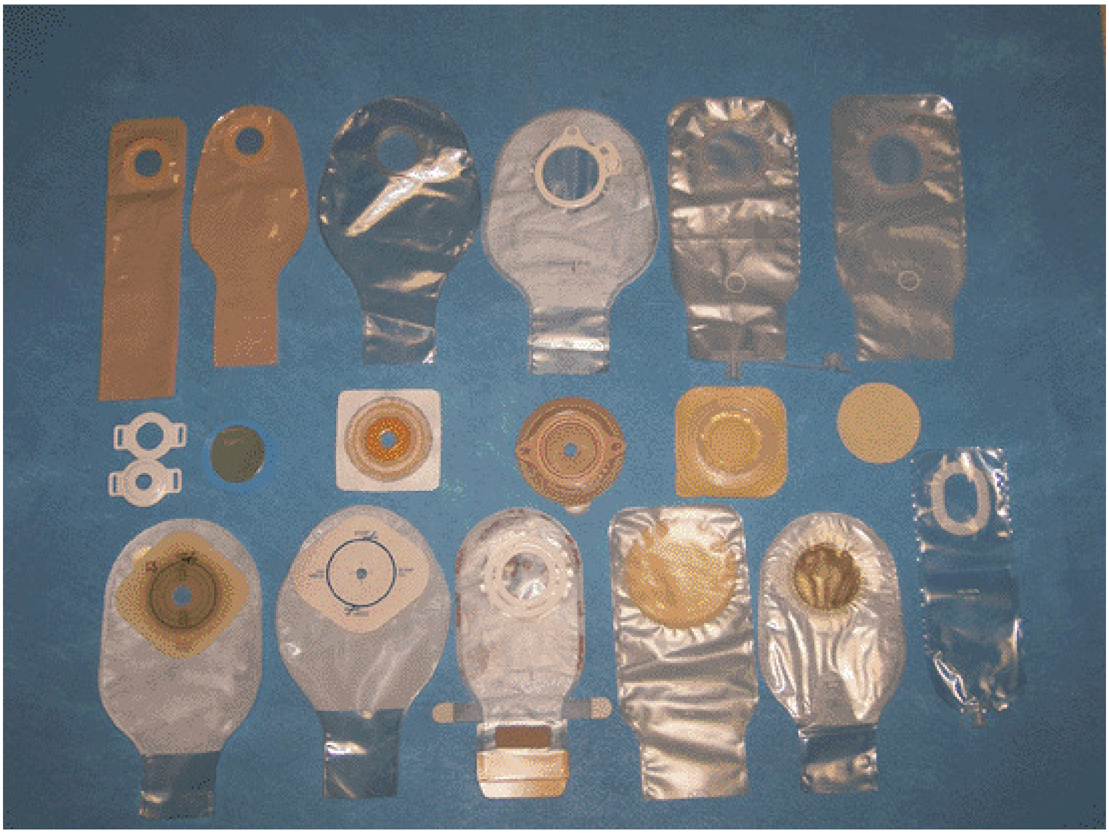

FIG 40.7. Examples of appliances for pouching a neonate.

G. Emptying the Pouch

- Supplies
  - Clean gloves
  - Diaper or syringe for withdrawing stool/effluent
  - 30- to 60-mL syringe for irrigating/washing the bag
  - Tap water
- The pouch should be emptied when it is one third to one half full. Gas must also be released or vented to prevent pulling the adhesive wafer away from skin. Neonates generally produce large amounts of gas, related to increased intake with sucking and crying (2). Effluent can be drained directly into a diaper or withdrawn from the bag with a syringe. Use of two or three cotton balls placed in an open-end pouch can improve wear time by wicking the effluent away from the barrier and also may facilitate easy drainage of the pouch. It is generally not necessary to wash the pouch, but it may be necessary to add fluid to help loosen up thick or pasty stool. For the hospitalized neonate, measurement of ostomy output is usually indicated.
- Close the pouch with a closure device or rubber band.

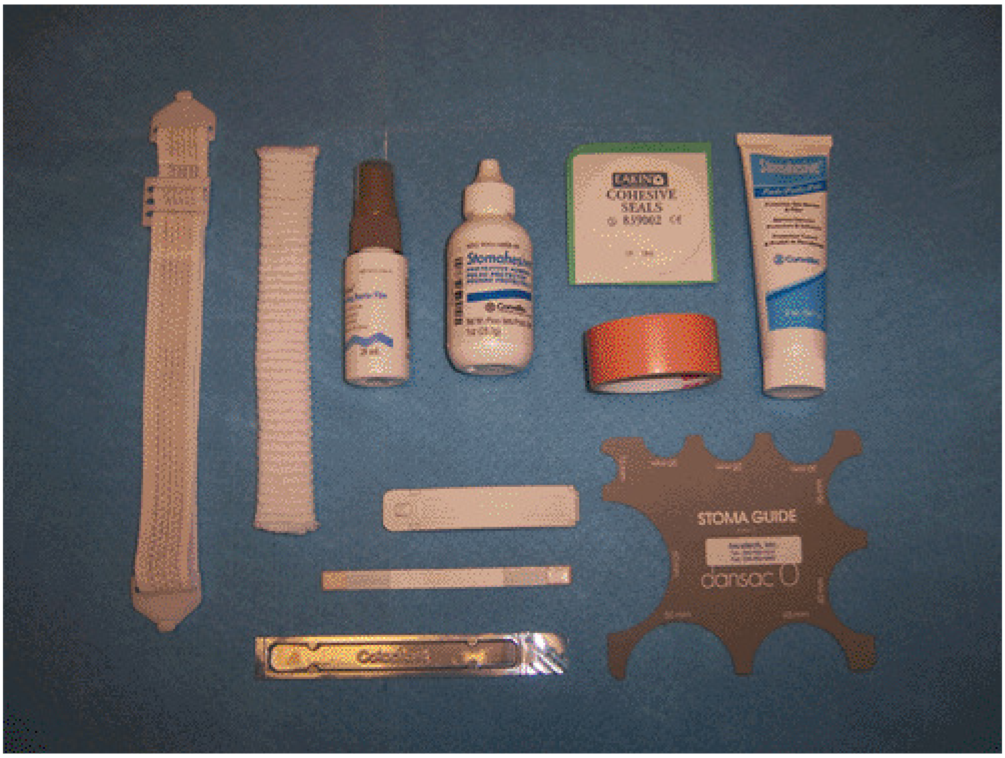

FIG 40.8. Examples of ostomy accessories.

H. Complicated Stomas and Peristomal Skin Problems (5,9)

Table 40.4 lists complications and interventions for treating complex stomas and common stoma problems. Note that many of items used are not generally recommended for use on premature neonates or neonates <2 weeks of age, but in situations of deterioration of the peristomal skin they are sometimes used cautiously to prevent further deterioration and maintain an effective seal.

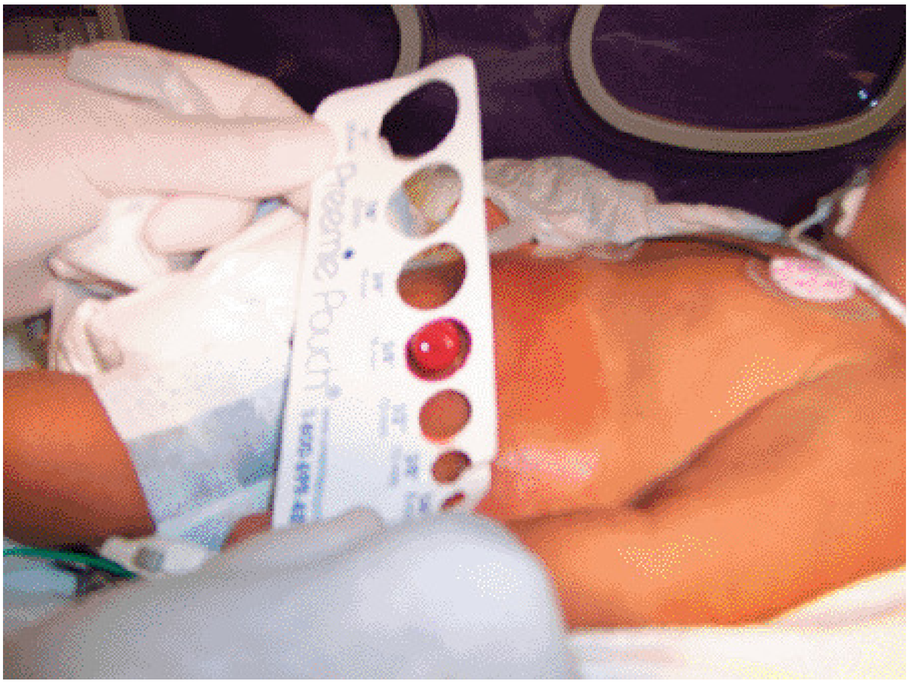

FIG 40.9. Measuring the stoma.

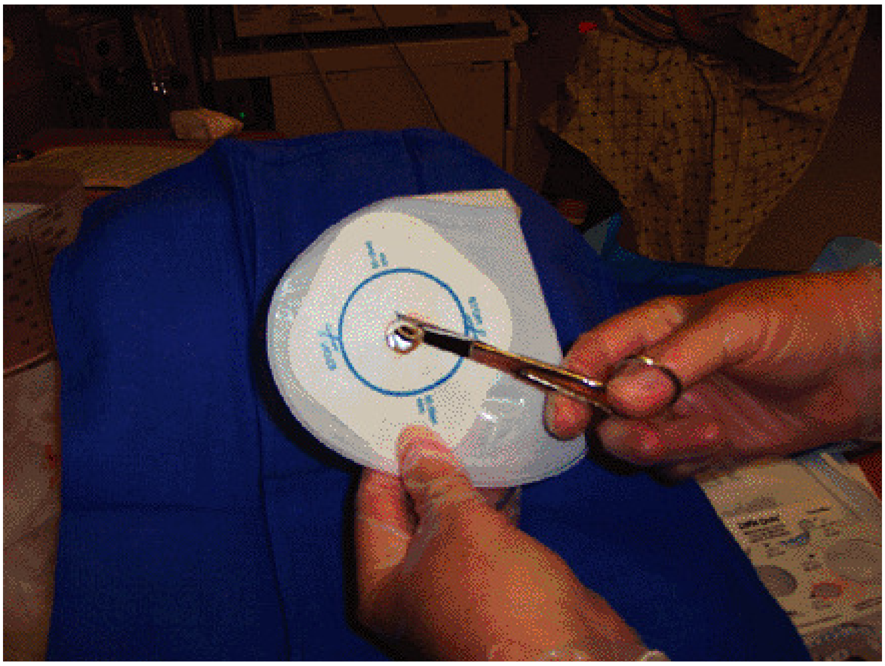

FIG 40.10. Cutting a hole in the wafer.

I. Vesicostomy Care

A vesicostomy does not require pouching; urine drains directly into the diaper. Care is similar to general perineal care of normal newborns (4). Occasionally, skin breakdown does occur; it can be treated with moisture barrier products and frequent diaper changes.

Gastrostomy Tubes

A. Indications

For indications and insertion technique, see Chapter 39.

B. Types of Tubes

See Table 40.5.

C. Gastrostomy Care

- Assessment
    - The health care provider must know if the patient has undergone a Nissen fundoplication or other antireflux procedure together with the gastrostomy.
    - Tolerance to feedings
    - Type and size of tube
    - Insertion site
    - Condition of the peristomal skin
- Special considerations for patients with Nissen or other antireflux procedure
    - Patient cannot vomit or burp.
    - Vent tube after crying and at first sign of gagging, discomfort, or distress.
- Gastrostomy tube site and routine skin care (6,10)
    - Clean gastrostomy tube site two to three times per day in the postoperative period and once per day after the site has healed. Use normal saline and sterile cotton swabs in the early postoperative period. Use mild soap and water after the site has healed. Diluted hydrogen peroxide (50% hydrogen peroxide and 50% water) is not recommended unless the site has dry, crusted blood (9).
    - Ensure that the antimigration device is flush against skin and the gastrostomy tube has not migrated.
    - Position tube at 90-degree angle.
    - A bottle nipple placed over the tube with the flanges resting on the abdominal wall may also be used to keep the tube at a 90-degree angle; secure with tape (Fig. 39.5).
    - Stabilize gastrostomy tube to prevent excess movement of tube, to decrease risk of stoma erosion, infection, bleeding, and development of granulation tissue.
    - Use an anchoring device (e.g., Hollister Tube Drainage Attachment Device, Hollister Inc., Libertyville, IL, USA) if the patient is allergic to tape or as a routine to secure the tube to skin.
    - Rotate bolster, flange of nipple, or wings of button every 4 to 8 hours to prevent pressure necrosis of skin. Do not place gauze between skin and bolster. A tension tab can be created by placing tape on the tube and pinning it to the diaper. A one-piece shirt with snap enclosure or tubular elastic dressing can also be used to cover the tube.
    - Assess site and peristomal skin for leaking, irritation, redness, rashes, or breakdown. Erythema and a minimal amount of clear drainage are to be expected in the first postoperative week.

D. Gastrostomy Tube Complications

Table 40.6 lists interventions for treating complications related to gastrostomy tubes.

TABLE 40.4 Complications and Complex Ostomies

Complication	**Interventions**
Multiple stomas	Customize pouch to fit around or accommodate stomas in bag; mucus fistulas may be in or out of pouch.
Open incision or wound	Two-piece pouches without starter hole may allow for easier customization. Keep wound as clean as possible. Use hydrocolloid wound dressing (e.g., DuoDerm, Convatec; Replicare, Smith and Nephew, Largo, FL, USA) or calcium alginate in wound bed covered with a piece of clear film dressing to protect wound from stool. Paste and powders may also be used to protect peristomal skin. In some cases it may not be possible to apply a pouch; however, the skin must be protected from caustic effluent. A combination of a skin barrier such as Sensicare (Convatec) and petrolatum has been found to be effective.
Flush/retracted stoma	Apply paste or moldable barrier around hole in wafer. Use convex insert/convex pouch and belt to push skin back and allow stoma to protrude.
Prolapsed stoma	Notify surgeon if evidence of circulatory compromise. Protect the stoma from injury. When using twopiece pouch with plastic flange, the stoma could be pinched in the flange that secures the pouch to the wafer when closed. Adjust size of hole accordingly; cover exposed skin with moldable barrier or paste.
Peristomal hernia	Use a flexible wafer and pouching system to adjust to contour of the skin.
Mushroom-shaped stoma	Modify opening to accommodate size of â€œcrownâ€□; protect skin around base with moldable barrier or paste.
Irritant dermatitis	Ensure that hole is cut to fit properly. Use paste to protect from leakage. Apply powder to open, weepy skin. Assess for sensitivity to products. Apply topical steroids if needed to decrease inflammation, pain, and itching.
Peristomal Candida albicans	Appears as red, shiny, macular, papular rash that is puritic. Apply topical antifungal powder (e.g., Mycostatin) to skin. The powder should be mixed with a small amount of water, painted smoothly on the skin with a cotton swab, and allowed to dry before placing the appliance. Continue to use with each pouch change until rash resolves. Dry skin completely when changing pouch. Resize pouch so that no skin is exposed.
Dehydration, metabolic acidosis, electrolyte imbalance	Monitor intake and output carefully, especially for infants with ileostomy and/or high output. Assess lab values regularly. Infants can develop electrolyte imbalance rapidly.

Data from refs. (3,4,5,6,7).

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TABLE 40.5 Types of Gastrostomy Tubes

Type	Description	Examples
Temporary/traditional	Most commonly used as initial tube following Stamm procedure; long, self-retaining catheters of latex or silicone rubber with self-retaining devices (i.e., balloon)	Malecott (Bard, Covington, GA, USA) (collapsible wings), dePezzer (mushroom)
Gastrostomy feeding tubes	Silicone catheter with antimigration device and end cap	MIC (Ballard Medical, Draper, UT, USA), Corpak (Med Systems, Wheeling, IL, USA)
Skin surface devices	Intended for use in established gastrostomy tract; have self-retaining devices, antimigration devices, and antireflux valves; two types, balloon and â€œMalecott type	Bard Button (Bard, Covington, GA, USA), Mic-key

TABLE 40.6 Interventions for Gastrostomy Tube Complications

Complication	Interventions
Leaking at insertion site	Ensure that tube is properly situated in stomach; pull back gently until resistance is met.
Stoma enlargement	Check water volume if balloon-type catheter. Ensure that tube is firmly secured to prevent erosion of mucosal lining and skin. Use proper feeding attachment. Ensure that tube is properly flushed and cleaned. Protect skin with skin barrier (e.g., Stomahesive wafer, paste or powder, Convatec; ILEX paste, Convatec; or hydrocolloid dressing). Use foam dressing (e.g., Hydrasorb, Convatec; Allevyn, Smith and Nephew) rather than gauze to wick moisture away from skin. If not contraindicated, consider H2-blocker and prokinetic agent. Placing larger-size tube may temporarily control leakage but will not amend problem and is contraindicated. Place smaller tube and secure well to allow stoma to contract around the tube.
Dislodgement	Do not reinsert if <2 wks postop. Contact surgeon immediately. If >2 wks postop, replace as soon as possible (see Chapter 39).
Bilious residuals	Assess for migration of tube (particularly if Foley is being used).
Bilious vomiting	Migration results from inadequate stabilization. Tube may migrate upward, causing vomiting and potential aspiration, or downward, causing gastric outlet obstruction.
Abdominal distention	Migration into the small intestine can cause â€œdumping syndrome. When using a balloon catheter and migration is not recognized, inflation of the balloon can lead to esophageal, duodenal, or small bowel perforation.
Pain	Pull back, if migrated, and secure. Vent tube. Consult surgeon if problem does not resolve.
Granulation tissue	Normal finding; caused by proliferation of granulation epithelial tissue in response to inflammation and irritation by foreign body. Prevent by stabilizing the tube. Treat by cauterizing with silver nitrate. For large amount of granulation tissue, consider applying Triamcinolone cream 0.5% 2-3 times daily until resolved.
Bleeding	Apply gentle pressure to site. Stabilize the tube. If granulation tissue is present, treat appropriately.
Irritant dermatitis	Protect skin with skin barrier (e.g., Stomahesive wafer, paste or powder, ILEX paste, or hydrocolloid dressing).

	Use foam dressing (e.g., Hydrasorb, Allevyn) rather than gauze to wick moisture away from skin. Assess for sensitivity to products/latex.
Candida albicans	Apply topical antifungal to skin. Control leakage. Dry skin completely after cleaning. Patient should also be assessed for oral thrush.
Clogged tube	Flush well after medications with 5 mL lukewarm water. A small amount (3-5 mL) of carbonated soda or cranberry juice may also be poured into the tube. Allow to set for 10 min, then flush with water.
Infection	G-tube site infections are uncommon; cellulitis is treated with systemic antibiotics.

Data from refs. (2,4,8,9,11).

Acknowledgment

The author acknowledges the work of Elizabeth E. Jarosz, Linda J. Haga and Jayashree Ramasethu, who wrote the chapter for the third edition of the Atlas, which formed the basis for this chapter.

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41-Transfusion of Blood and Blood Products

Naomi L.C. Luban

Overview

Blood Products Utilized in Neonates

- Packed red blood cells (PRBCs)
- Whole or reconstituted whole blood
- Platelet concentrates derived from whole blood or plateletpheresis
- Fresh frozen plasma (FFP) or frozen thawed plasma
- Cryoprecipitate
- Granulocyte concentrates derived from granulocytopheresis

Sources of Blood Products

- Banked donor blood
- Directed donor transfusions
- Autologous fetal blood transfusions

Indications, requirements, and transfusion techniques differ for each procedure and component. Simple transfusions are discussed in this chapter. Exchange transfusions are discussed in Chapter 42. Complications common to all blood products are listed later in this chapter.

A. Precautions

- Whenever possible, obtain informed consent prior to transfusions, delineating risks, benefits, and alternatives to transfusion.
- Limit use of transfusions to justified indications.
- Select blood product appropriate for infant's condition.
- Confirm with proper identifiers at bedside that blood product is for correct patient. Maintain all records relevant to collection, preparation, transfusion, and clinical outcome.
- Avoid excessive transfusion volume or rate unless acute blood loss or shock dictates faster transfusion.
- Store blood and blood products appropriately. Freezing and lysis may occur if red blood cells (RBCs) are stored in unmonitored refrigerators.
    - Use blood bank refrigerator for storage of RBCs, whole blood, thawed FFP, and thawed cryoprecipitate.
    - Temperature should be controlled at 4 Â± 2Â°C with constant temperature monitors and alarm systems.
    - Refrigerator should be quality-controlled at least daily.
    - Designated for blood products only
    - Store platelets at 20 to 24Â°C with continuous agitation.
- PRBCs and whole blood should be out of refrigeration for <4 hours to minimize bacterial contamination and red blood cell hemolysis.
- Use approved blood warming services for PRBCs and whole blood. Syringes for aliquots must not be warmed in water baths because of the risk of contamination.
- Stop transfusion or slow rate if baby manifests any adverse side effects.
    - Tachycardia, bradycardia, or arrhythmia
    - Tachypnea
    - Systolic blood pressure increases of >15 mm Hg, unless this is the desired effect

  - Temperature above 38Â°C
  - Hyperglycemia or hypoglycemia
  - Cyanosis
  - Skin rash, hives, or flushing
  - Hematuria/hemoglobinemia
  - Hyperkalemia
- Transfuse RBCs cautiously in incipient or existing cardiac failure.
  - Monitor heart rate, blood pressure, and peripheral perfusion.
  - Transfuse PRBCs, or
  - Consider partial exchange transfusion:
    - With hemoglobin level <5 to 7 g/dL
    - With cord hemoglobin <10 g/dL
- Prevent fluctuations in glucose during RBC transfusion:
  - In infants weighing <1,200 g or in other unstable infants, to prevent hypoglycemia
    - Do not discontinue parenteral glucose administration.
    - Establish separate intravenous line for blood administration.
  - When transfused blood has elevated glucose concentration, expect rebound hypoglycemia in infants with hyperinsulinism.

B. Pretransfusion Testing and Processing (1, 2)

- Blood group and Rh type
  - Maternal ABO blood group and Rh type: Screen maternal serum for atypical antibodies.
  - Baby's ABO blood group and Rh type: Screen baby's serum for atypical antibodies if maternal blood is unavailable.
  - Cord blood may be used for initial testing.
  - Baby's blood group is determined from the red cells alone, because the corresponding isoagglutinins anti-A and anti-B are usually weak or absent in the serum.
- Cross-matching
  - Compatible blood may be low-anti-A, anti-B titer Group O Rh-negative blood or blood of the infant's ABO group and Rh type (except in alloimmune hemolytic disease of the newborn).
  - Conventional cross-match is not required if infant <4 months old and no atypical antibodies are detected.
  - Compatibility testing for repeated small-volume transfusions is usually unnecessary, because formation of alloantibodies is extremely rare in the first 4 months of life.
  - If antibody screen is indirect antiglobulin test (IAT)-positive in mother or baby:
    - Serologic investigation to identify antibody(ies) is necessary.
    - Full compatibility testing is required.
    - If anti-A or anti-B detected in infant, infant should receive RBC lacking A or B antigen until antibody screen is negative.
  - If infant has received large volumes of plasma or platelets, passive acquisition of antibodies may occur; cross-matching is recommended.
  - If directed donor blood from a parent is used, cross-matching is required.
- Specially processed products
  - Blood donated in the United States is tested for human immunodeficiency virus (HIV), human T-lymphotropic virus I/II, hepatitis B and C viruses, West Nile virus, syphilis, and bacteria (in platelet products).
  - Cytomegalovirus (CMV)-seronegative or third-generation leukodepleted (LD) blood is recommended for infants with birthweight 1,200 g born to seronegative mothers or those with unknown serostatus (1).
  - Use of universal LD and/or CMV seronegative products is institution-specific (3).
- Irradiation to prevent transfusion-associated graft-versus-host disease (TAGVHD)

  - Whole blood, PRBCs, previously frozen RBCs, granulocyte and platelet concentrates, and fresh plasma have been implicated in TAGVHD; LD products have also been implicated.
  - Clinical indications for irradiated blood components are (1, 2, 4, 5 and 6)
    - Intrauterine transfusion
    - Premature infants, variably defined by weight and postgestational age
    - Congenital immunodeficiency suspected or confirmed
    - Undergoing exchange transfusion for erythroblastosis
    - Hematologic/solid organ malignancy
    - Recipient of familial blood donation
    - Recipient of HLA-matched product
  - Some institutions provide irradiated blood products to all neonates to avoid TAGVHD in patients with undiagnosed immunodeficiency.

C. Equipment

- Blood product (see Appendix C)
- Cardiorespiratory monitor
- Blood: All blood and blood components must be filtered immediately prior to transfusion despite prestorage LD. Many transfusion services supply PRBCs and occasionally platelets and cryoprecipitate prefiltered to the neonatal intensive care unit (NICU).
  - Administration set with in-line filter of 120- to 170-Âµm pore size to be used for all products
  - Microaggregate filter, 20- to 40- Âµm pore size
    - Must follow manufacturer's instructions
    - Some function only if product is dripped
    - Not advisable for syringe administration
    - Usefulness questionable and unnecessary if LD and/or additive RBC's used
  - Prestorage LD filtration (2, 3, 6)
    - Removes 99.9% of white blood cells (WBCs) or 3 log leukodepletion
    - Must follow manufacturer's instructions
    - Attenuation/abrogation of CMV and other viruses (Epsteinâ€“Barr, HTLV I/II Human Thymphocyte Virus) harbored in WBCs
    - LD performed by collecting facility preferred to bedside use
- Sterile syringe
- Blood administration set
  - a May be manufactured with integral 120- to 170-Âµm filter
  - May not be needed if prefiltered product is dispensed from transfusion service
  - Blood warmer not needed
- Automated syringe pump with appropriate tubing and needle (7, 8, 9, 10, 11 and 12)
  - Least hemolysis occurs with straight syringe pumps
  - Vascular access: PRBCs may be transfused through 24-, 25-, or 27-gauge needles and short catheters but not through 27- or 28-gauge central venous catheters.
  - The amount of hemolysis that results from infusion of RBCs is directly proportionate to the age of the blood and the rate of transfusion and inversely proportional to needle size.
  - Hyperkalemia, hemoglobinuria, and renal dysfunction may result if hemolyzed blood is transfused.
- Normal saline flush (1 mL or more) to clear intravenous solution from line.

Packed Red Blood Cell Transfusions

A. Indications

- Guidelines and justifications for transfusions are controversial and vary among different authorities and institutions (13, 14). The transfusion guidelines followed by the U.S. Multicenter Recombinant Human Erythropoietin Trial established the safety, at least in the short term, of conservative transfusion practices for infants needing mild and moderate respiratory support (Table 41.1) (15). Transfusion guidelines continue to be liberal for infants with severe cardiorespiratory compromise (4). Limiting transfusion is now questioned as a cause of central nervous system complications and apnea (16).
- In general:
  - Replace acute blood loss.
  - Correct anemia that is compromising cardiovascular status or oxygen-carrying capacity.

B. Contraindications

- None absolute
- Exert caution in patient with:
  - Volume overload
  - Congestive heart failure
  - T-activation

TABLE 41.1 Guidelines for Transfusion of RBCs in Patients <4 Months of Age

1. Hematocrit <20% with low reticulocyte count and symptoms of anemia[a]
2. Hematocrit <30% with an infant:
   a. On >35% hood O_2
   b. On O_2 by nasal cannula
   c. On continuous positive airway pressure and/or intermittent mandatory ventilation with mechanical ventilation with mean airway pressure <6 cm H_2O
   d. With significant apnea or bradycardia[b]
   e. With significant tachycardia or tachypnea[c]
   f. With low weight gain[d]
3. Hematocrit <35% with an infant:
   a. On >35% hood O_2
   b. On continuous positive airway pressure/intermittent mandatory ventilation with mean airway pressure 6 cm H_2O
4. Hematocrit <45% with an infant:
   a. On extracorporeal membrane oxygenation
   b. With congenital cyanotic heart disease

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[a] Tachycardia, tachypnea, poor feeding.

[b] More than six episodes in 12 hours or two episodes in 24 hours requiring bagand-mask ventilation while receiving therapeutic doses of methylxanthines.

[c] Heart rate >180 beats/min for 24 hours, respiratory rate >80 breaths/min for 24 hours.

[d] Gain of <10 g/day observed over 4 days while receiving 100 kcal/kg/day.

Source: Adapted from **Roseff SD, Luban NL, Manno CS**. Guidelines for assessing appropriateness of pediatric transfusion. *Transfusion.* 2002;42:1398-1413.

C. Technique

- Determine total amount of blood needed.
    - Calculate volume of blood for transfusion. Most infants are transfused 10 to 15 mL/kg of PRBCs, which will increase the hemoglobin by 3 g/dL.
    - Calculate volume of PRBCs required:

      [EBV — (Hct desired - Hct observed)] Hct of PRBC unit

      where EBV is the estimated patient's blood volume, approximately 80 to 85 mL/kg in full-term infants and approximately 100 to 120 mL/kg in preterm infants, and Hct is hematocrit.

- Include volume of blood needed for dead space of tubing, filter, pump mechanism (varies from system to system; may be as much as 30 mL).
- Obtain blood product (see Appendix C).
    - Several studies have documented the safety of using PRBCs stored in additive anticoagulant preservative solutions to outdate.
    - Avoid use of RBCs stored in additive-containing solutions for massive transfusions, unless the additive is removed by inverted storage or centrifugation; risks of hyperosmolality, hyperglycemia, hypernatremia, hyperkalemia, hyperphosphatemia are postulated (17).
    - In infants receiving 10 to 15 mL of PRBCs, the amount of K^+ delivered by the transfusion is estimated to be only 0.15 mEq/kg and does not pose a significant risk to most neonates.
    - Donor exposures are reduced by repeatedly obtaining small aliquots of PRBCs from dedicated units until the outdate of 35 to 42 days (Figs. 41.1 and 41.2) (18, 19).

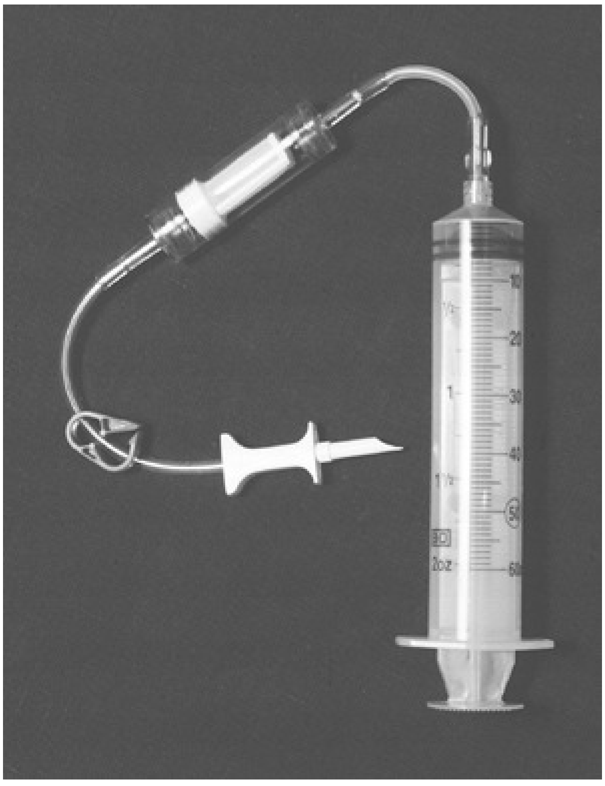

FIG. 41.1. Neonatal syringe set with filter. (Courtesy of Charter Medical Ltd., Winston-Salem, NC, USA). This system, when used with sterile connection technology, provides a closed delivery system that maintains primary unit outdate. Syringe blood aliquots (PRCBs, plasma) must be administered to the patient within 24 hours and syringe platelet aliquots within 4 hours.

- Verify whether cross-matched product is necessary or unâ€“cross-matched product is adequate.
- Confirm that restrictions have been adhered to on blood product and transfusion tag.
    - CMV: Tested/untested
    - Irradiated: Yes/no
    - Directed (familial) donation: Yes/no
    - RBC antigen-negative: Yes/no
    - Sickle tested-negative: Yes/no
    - Other restrictions specified: Yes/no
- Verify appropriateness of blood selected for patient by comparing blood product and unit tag (integral to blood unit) information and patient identification. Bar-code reading devices are advisable.
    - Blood unit tag and blood bag
    - Patient hospital or medical record number
    - Patient identification by armband or footband
    - Blood group and type of both donor and recipient
    - Expiration date and time and restrictions on unit and order
    - Restrictions as ordered by physician or by institutional guidelines
- Warming PRBCs (2, 20, 21)
    - There is no need to warm small-volume PRBC aliquots, particularly if the transfusion is given over 2 to 3 hours.
    - PRBCs may be warmed by placing the syringe beside the infant in the warm-air incubator for 30 minutes prior to transfusion.
    - Inappropriate warming by exposure of blood to heat lamps or phototherapy lights may produce hemolysis.
- Adhere to sterile technique throughout procedure.
- If prefiltered PRBCs are provided by the blood bank in a syringe, attach tubing directly to syringe.
- If PRBCs are provided in a bag, use large-bore needle (18-gauge or larger) to withdraw volume into syringe. Filter should be placed between bag and syringe (Fig. 41.1).
- Prime tubing with blood. Clear syringe and tubing of bubbles, and mount into infusion device.
- Verify patency of vascular access.
- Clear line into patient with normal saline.
- Record and monitor vital signs.
- Determine spot glucose test. Repeat hourly as needed.
- Begin transfusion at controlled rate: 5 mL/kg/hr.
- Gently invert container of blood every 15 to 30 minutes to minimize sedimentation.
- Stop transfusion if any adverse change in condition occurs.
- At end of infusion, clear blood from line with saline.
- Check recipient hemoglobin and hematocrit, if necessary, at least 2 hours after transfusion.
- If posttransfusion hematocrit/hemoglobin is not up to expected level, consider:

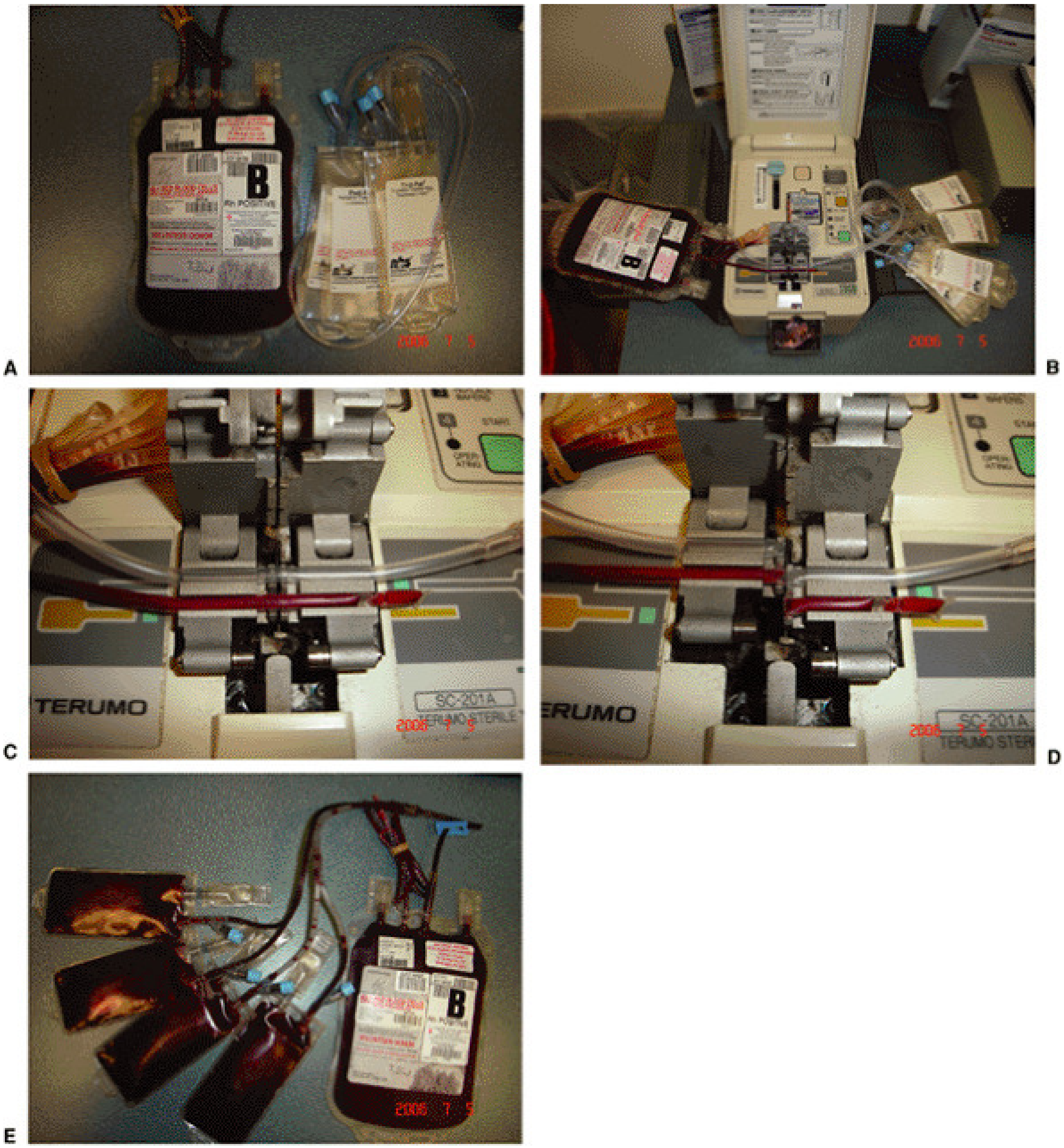

FIG. 41.2. Use of a sterile connecting device. A: An adult RBC unit is shown along with a set of pediatric transfer bags. The transfer bags can be attached by spiking the unit, causing it to expire in 24 hours; alternatively, the transfer bags can be connected using a sterile connection device. B, C: The separate tubings are loaded into the tubing holders of the device. The covers are closed. D: A welding wafer heated to about 500Â° F melts through the tubing. The tubing holders realign and the welding wafer retracts allowing the tubing ends to fuse together. E: The unit can now be aliquoted as needed. Because a functionally closed system has been maintained, the expiration date of the blood has not changed.

- Low hematocrit of PRBC unit
- Inappropriate calculation of transfusion requirement
- Ongoing blood loss
- Transfusion reaction
- Hemolysis due to ABO or other RBC incompatibility
    - Infant has circulating anti-A, anti-B, and anti-AB, which is bound to A or B antigens on transfused RBCs.
    - Direct antiglobulin test (DAT) negative initially but now positive

- Unexpected increase in bilirubin
- Infant has RBC antibody other than ABO.
- Hemolysis from extrinsic damage (mechanical) to RBCs or donor has hemolytic disorder.

Whole or Reconstituted Whole Blood

Reconstituted whole blood is prepared by adding a unit of RBCs to a compatible unit of FFP (1, 2). Levels of coagulation factors V and VIII are low, platelet function is grossly abnormal, and concentration of K^+ is high in stored whole blood. Transfusion of PRBCs and other blood components as required is preferable to the use of stored whole blood.

A. Indications

- Massive transfusion as in acute blood loss, when restoration of blood volume and oxygen-carrying capacity are needed simultaneously.
- Exchange transfusions
- Cardiopulmonary bypass
- Extracorporeal membrane oxygenation
- Continuous hemofiltration
- In children <2 years of age, transfusion of fresh (<48 hours old) whole blood has been associated with significantly less postoperative blood loss following bypass surgery for complex congenital heart disease (22). Recent studies now question use of whole blood (23).

TABLE 41.2 Guidelines for Platelet Transfusions (Ã— 10^9/L)

	Nonbleeding, Sick, Preterm	Nonbleeding Stable, Preterm	Nonbleeding, Term	Before Invasive Procedure	Actual Bleeding
Roberts (2006) Canada	<50	<30	<30	<50	<100
Roseff (2002) USA	<100	<50	<30	<50 if failure of products	<50 if stable <50 if sick
Gibson (2004) UK	<30	<20	<20	<100 if DIC Not specified	<50

â€œSickâ€□ infants in this context defined as those with a history of perinatal asphyxia, extremely low birthweight (<1,000g), need for ventilatory support with an inspired oxygen concentration >40%, clinically unstable, signs of sepsis, or those who require numerous invasive interventions.

B. Precautions

- Not suitable for simple transfusion for anemia
- Not suitable for correction of coagulation factor deficiencies
- Hyperkalemia may result from rapid transfusion of large volumes (10, 11, 24).
- Anticoagulant effects must be considered (17).

C. Equipment and Technique

- Same as for PRBCs
- The rate of transfusion may be increased to 10 to 20 mL/kg/hr to replace acute blood loss.
- When used for complex mechanical procedure, 120- to 150-Âµm filters often in line to device.

Platelet Transfusions

A. Indications (Table 41.2)

The platelet count at which transfusion is recommended has to be individualized, because hemostatic competence is determined not only by the quantity of platelets but also by platelet function, vascular integrity, levels of coagulation factors, and underlying disorder/disease.

B. Contraindications

Because the half-life of platelets is reduced in conditions of rapid consumption and/or immune destruction, platelet transfusions often do not produce a measurable platelet increment. Their use in these conditions is reserved for life-threatening situations in which other therapy is ineffective. In infants previously exposed to heparin, who develop thrombocytopenia, and platelet refractoriness, consider heparin-induced thrombocytopenia as cause (25). Poor posttransfusion increment in infants with neonatal alloimmune thrombocytopenia (NAIT) can define diagnosis (26).

C. Equipment and Technique

- Platelets
  - Random donor platelet concentrate (5.5 3 Ã— 10^{10} platelets in 40 to 70 mL of plasma)
    - Separated from whole blood by centrifugation within 8 hours of blood draw
    - Resuspended in plasma
    - Shelf life of 5 days
  - Volume-reduced platelets
    - Standard platelet concentrate concentrated to a volume of 15 to 20 mL by centrifugation (27)
    - Associated with loss of platelets and possible decrease in platelet function
    - Shelf life reduced to 4 hours
    - Use only if infant has oliguria, severe volume load sensitivity
  - Plateletpheresis (3 Ã— 10^{11} platelets in volume of 250 mL plasma)
    - Removes only platelets, returns RBCs and plasma to donor
    - Usually leukodepleted before storage
    - Permits repeated donations from same donor every 48 hours under select circumstances
    - High yield of platelets
    - More expensive product
    - Useful when multiple platelet transfusions of a particular antigen specificity are required, as in neonatal albimmune thrombocytopenia (NAIT) or for infants on extracorporeal membrane oxygenation (ECMO) needing multiple platelet transfusions.
    - May be HLA-typed or typed for PLA1 or other specific platelet antigen in case of NAIT.
    - Maternal plateletpheresis product is preferred for NAIT. Use maternal antigen-negative platelets, washed, irradiated, and resuspended in group-compatible ABO plasma or saline.
- Calculate volume of platelets to transfuse based on type of product.
  - 10-15 mL/kg of random platelet provides 10 Ã— 10^9 platelets/kg and should increase platelet count to >50 Ã— 10^9/L in the absence of ongoing consumption.
  - Can use same calculations for apheresis platelets, but studies do not confirm posttransfusion increments. Advise use of equivalent unit calculations and not mL/kg.
  - Other products (HLA-typed, cross-matched platelets) used for platelet (PLT) refractoriness; washed PLTs if using PLT antigen-matched maternal PLTs.

- Blood administration set with 120- to 170-Âµm in-line filter, unless platelets have been prefiltered while drawing into a syringe. Specific sets designed for plasma/ platelets have in-line filters with reduced surface area to increase platelet transfusion efficacy.
- Sterile syringe for automated pump infusion. Use of syringe technique will increase damage to platelets. Administer by drip if clinically feasible.
- Automated syringe pump
- Connecting intravenous tubing
- Intravenous access, preferably through 23-gauge or larger needle or through umbilical venous catheter
- Normal saline flush solution

D. Precautions

- Use type-specific (Rh-negative) platelets when potential for sensitization is present (i.e., in Rh-negative female). Although platelets do not have Rh antigens, all products have some red blood cell contamination (less in plateletpheresis), which may cause Rh sensitization (28).
- Use platelets from donor with ABO-compatible plasma (Table 41.3). Isohemagglutinins in ABO-incompatible plasma may result in hemolysis, a positive DAT, and poorer in vivo platelet survival than anticipated.
- Transfuse platelets as soon after preparation as possible. Platelets should never be refrigerator-stored or warmed.
- Platelets should not be infused through arterial lines.

E. Technique for Platelet Administration by Automated Syringe

- Estimate by weight the volume of platelets in a single bag to determine fluid load to infant.
- Confirm correct platelet product.
    - Infant and unit identification

TABLE 41.3 Choice of Platelets

Baby	**Door**
O	O
A	A, AB
B	B, AB
AB	AB

-
    - Infant and donor blood group, and Rh type
    - Check other restrictions: CMV negative, irradiated, etc.
- Attach, aseptically, in sequence:
    - Platelet concentrate or bag aliquot
    - Platelet administration set, including filter
    - Three-way stopcock
    - Transfusion syringe
- Draw into syringe volume of platelets for transfusion and tubing dead space. Clear air bubbles.
- Remove syringe from three-way stopcock and attach to connecting tubing.
- Establish IV access. If infant is at risk for hypoglycemia with interruption of continuous glucose source, start new IV or monitor closely throughout infusion.
- Clear IV of glucose solution with 1 mL or more of normal saline.
- Attach connecting tubing and syringe to IV line.
- Monitor patient's vital signs.
- Infuse platelets over 1- to 2-hour period, faster if tolerated by infant.

- After infusion is complete, flush IV line with 1 mL of normal saline before restarting glucose solution.
- Determine survival time of transfused platelets by obtaining platelet counts at 1, 2, or 24 hours.

F. Complications

See list of complications for all blood products (1, 2, 29).

- Accentuated hemolysis in sensitized but IAT-negative ABO setup
- Rh sensitization in Rh-negative recipient (28)
- Volume overload
- Allergic reactions, including hypotension
- Transfusion-related lung injury (TRALI) (30, 31)
- Increased morbidity in necrotizing enterocolitis (NEC) (32)

Granulocyte Transfusions

A. Indications

- Granulocyte transfusions are used infrequently, displaced by improved cidal antibiotics, supportive care, and, in rare circumstances, use of granulocyte- and granulocyte/macrophage-stimulating factors (33).
- Historical indications not confirmed in randomized trials to be relevant:
    - Neonates <14 days old, with bacterial sepsis and neutropenia (neutrophil plus band count <3 — 10^9/L)
    - Older neonates with bacterial sepsis, unresponsive to antibiotics with neutrophil and band counts <0.5 — 10^9/L

B. Equipment and Technique

- Granulocyte concentrates for neonatal use should be prepared by automated granulocytapheresis and contain 1 to 2 — 10^9 neutrophils in 10- to 15-mL/kg volume. Steroid- or G-CSF-mobilized donor preferred.
- Daily transfusions may be necessary until there is clinical improvement and evidence of recovery of neutrophil counts.
- Component must be ABO- and Rh-compatible with recipient, and cross-match-compatible.
- Product should be irradiated, CMV-negative, and infused as soon as possible after collection.
- The product should not be refrigerated or warmed above room temperature.
- Standard 120- to 170-Âµm filters should be used for infusion; microaggregate and leukodepletion filters must be avoided.

C. Precautions

Storage of product for >8 hours is associated with a rapid decrease in WBC function, making this a less than useful product. Fever, alloimmunization, TRALI, and CMV have all been reported complications.

Fresh Frozen Plasma, Frozen Thawed Plasma, and Cryoprecipitate

A. Indications (2, 34)

Clinically significant bleeding or for correction of hemostatic defects prior to invasive procedures in the presence of

- Complex factor deficiency unresponsive to Vitamin K
- Isolated congenital factor deficiency for which virus-inactivated-plasma-derived or recombinant factor concentrates are unavailable
- Congenital or acquired dys- or hypofibrinogenemia (cryoprecipitate is preferred)

B. Contraindications

- None absolute
- Exert caution when possibility of volume overload exists.
- Necrotizing enterocolitis (NEC): Use with caution. May aggravate hemolysis in infant with NEC and T-activation (35, 36).
- Not indicated for hypovolemic shock in the absence of bleeding, nutritional support, treatment of immunodeficiency, or prevention of intraventricular hemorrhage.

C. Equipment and Technique
See Platelet Transfusion.

- Cross matching is not required because type-specific or AB-negative product is usually issued.
- Dose of FFP is 10 to 20 mL/kg; multiple transfusions may be required until the underlying condition resolves.
- Once thawed, FFP should be transfused within 6 hours for labile factor replacement.
- In cases for which repeated FFP transfusions are required, a thawed unit from a single donor may be divided into smaller aliquots and used within 24 hours if stored between 1 and 6Â°C.

Directed Donor Transfusions

A. Potential Problems

Directed donations provide no known benefit in terms of increased safety and may have several disadvantages (37):

- Possible increased risk of transmitting infectious disease because directed donors are often first-time or infrequent donors with no track record of safety, unlike established volunteer donors, whose screening tests are negative repeatedly.
- Possibility of serologic incompatibility between the recipient baby and the family donors.
  - Plasma of biologic mothers may contain alloantibodies to blood cell antigens inherited by the infant from the father, which may lead to hemolysis, thrombocytopenia, and WBC aggregation in the infant, when transfused without the protective barrier of the placenta.
  - Paternal blood cells may express antigens to which the neonate may have been passively immunized by transplacental transfer of maternal antibodies.
  - Routine pretransfusion testing may not detect these serologic incompatibilities, which may result in hemolytic or other transfusion reactions.
- Although biologic parents may be interested in donating for their infants, many are likely to be ineligible for medical or serologic reasons.

B. Precautions

- Directed donations must be screened as stringently as volunteer donations.
- Biologic mothers should not provide blood components containing plasma; maternal red cells and platelets should be given as washed concentrates.
- Fathers and paternal blood relatives should preferably not serve as donors for blood components containing cellular elements; a full antiglobulin cross-match should be performed to detect red cell incompatibilities if their use is unavoidable.
- All blood components obtained from first- or second-degree relatives should be irradiated prior to transfusion.

Autologous Fetal Blood Transfusions (38,39,40,41)

A. Indications

- Delivery room resuscitation of infants with shock and profound anemia, when O Rh-negative bank blood is not readily available.
- Source of autologous PRBCs for elective transfusion to preterm infants.
- Source of cord blood for freezing for hematopoietic reconstitution.

  Protocols for proper collection with appropriate anticoagulation, without bacterial contamination, are still being refined for these indications.

B. Contraindications

- Maternal infection
  - Chorioamnionitis
  - Sepsis
  - Hepatitis, HIV
- Prolonged rupture of membranes >24 hours

C. Complications

- Bacterial sepsis from contaminated collection
- Insufficient volume collected for transfusion
- Over/undercollection for volume of anticoagulant used

Complications of Blood Transfusions

Transfusions are safer now than ever before, but they are not risk-free (4, 5).

- Transmission of infectious diseases (42, 43)
  - Viruses: Risk varies geographically
    - Human immunodeficiency virus: Estimated potential risk in United States from a blood donor with negative serologic tests is <1 in 2,135,800.
    - Human T-lymphotropic virus I and II: Risk 1 in 641,000
    - Hepatitis B virus: Risk 1 in 1,205,000
    - Hepatitis C virus: Risk 1 in 1,935,000
    - Hepatitis A virus: Risk 1 in 1,000,000, asymptomatic in newborn, but may cause symptomatic infection in adults who are in contact with infected neonates.

        - Cytomegalovirus: Transmitted by cellular blood products, not transmitted by FFP or cryoprecipitate; risk of transfusion transmitted CMV from cellular blood components from CMV-seropositive donors 8% to 25%, risk of CMV infection after transfusion of CMV-seronegative or effectively leukoreduced components is <1% to 4%.
        - Hepatitis G, parvovirus B-19, Epsteinâ€"Barr virus
    - Bacteria (44)
        - Persistent problem, often unrecognized
        - Platelet concentrates and PRBCs most often implicated
        - Organisms: Yersinia enterocolitica, Serratia, and Pseudomonas genus for RBCs; Staphylococcus epidermidis, Bacillus species for platelets.
        - Treponema pallidum: Does not survive refrigeration; syphilis reported after transfusion of fresh blood.
        - Red cell units with gross bacterial contamination may occasionally be identified by the darker color of the blood in the bag compared with the color of blood in the tubing.
    - Protozoan
        - Malaria: Rare in the United States but reported even in nonendemic areas (45)
        - Babesiosis
        - Chagas disease
    - Creutzfeldtâ€"Jacob
        - Few proven cases of transfusion-transmitted new-variant Creutzfeldtâ€"Jacob disease at present (46)
        - Most blood collection centers attempt to minimize the risk by excluding donors considered to be at higher risk for possibly harboring the infection, by family and travel history and specific medical history (2).
- Hemolytic reactions
    - Acute hemolytic immunologic reactions: Rare, because of absence in infant of naturally occurring anti-A or anti-B antibodies, and infrequent posttransfusion red cell alloimmunization despite multiple transfusions.
    - T-activation: A severe form of immune-mediated hemolysis is associated with the transfusion of adult blood containing anti-T antibodies in neonates with activation of the normally cryptic T-antigen on the surface of neonatal red cell membranes (35, 36).
        - Common in premature infants and associated with necrotizing enterocolitis and sepsis
        - Suspect T-activation in neonates at risk with intravascular hemolysis, hemoglobinuria, hemoglobinemia following transfusion of blood products, or unexpected failure to achieve posttransfusion hemoglobin increment.
        - Routine cross-matching will not detect T-activation when monoclonal antiserum is used.
        - Diagnosis: By minor cross-matching, discrepancies in forward and reverse blood grouping, confirmed by specific agglutination tests using peanut lectins.
        - Use washed red cells, platelets, and low-titer anti-T plasma only when hemolysis is confirmed (35).
- Nonimmunologic causes of hemolysis
    - Mechanical, through excessive infusion pressure through small needles or 20- to 40-Âµm filters
    - Accidental overheating or freezing of blood
    - Simultaneous administration of incompatible drugs and fluids
    - Transfusion of abnormal donor cells (glucose 6-phosphate dehydrogenase deficiency, hereditary spherocytosis)
- Other immunologic reactions
    - Transfusion-associated graft-versus-host disease

    See processing with irradiation for risk factors and prevention.

  - Transfusion-related acute lung injury
    - Secondary to transfusion of donor blood containing antigranulocyte and anti-HLA antibodies, leukoagglutinins directed against recipient granulocyte antigens, or to transfusion of plasma cytokines/mediators that affect recipient granulocytes, causing pulmonary endothelial adhesion defects
    - Initiates life-threatening hypoxemia secondary to complement activation and microvascular lung injury
    - Rarely reported in neonates; may be difficult to distinguish from other causes of respiratory deterioration in sick infants.
- Circulatory overload

  Alterations in pulmonary compliance and blood pressure

- Adverse metabolic effects
  - Hyperkalemia
    - Blood that is irradiated and then refrigerator-stored may have K^+ levels of 30 to 50 mEq/L or higher in the supernatant plasma.
    - Small-volume transfusions of stored red cells do not cause clinically significant elevations in serum K^+ levels.
    - Life-threatening hyperkalemia has been described in sick infants and in those receiving rapid infusions of large volumes of stored red cells.
    - Washed or fresh (<14 days) red cells are recommended for infants with profound hyperkalemia, renal failure, or when large volumes are transfused rapidly.
  - Hypoglycemia or hyperglycemia
  - Hypocalcemia
  - Alterations in acidâ€“base balance with large transfusions

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42-Exchange Transfusions

Jayashree Ramasethu

The frequency with which postnatal exchange transfusions (ET) were performed decreased in the 1990s, resulting in significantly less experience among personnel performing the procedure (1, 2, 3). However, the re-emergence of kernicterus as a public health problem underscores the importance of ET as a treatment modality that could potentially prevent devastating neurodevelopmental complications (4, 5).

A. Definitions

- Exchange transfusion: Replacing an infant's blood with donor blood by repeatedly removing and replacing small aliquots of blood over a short time period

B. Indications

- Significant unconjugated hyperbilirubinemia in the newborn due to any cause, when intensive phototherapy fails or there is risk of kernicterus. Immediate ET is recommended if there are early signs of acute bilirubin encephalopathy (6). Figure 42.1 shows the total serum bilirubin levels at which ET is recommended for infants of 35 or more weeks' gestation.
- Indications for ET in more immature infants are variable and individualized (see Table 46.1). When performed for low bilirubin levels, ET is less effective than phototherapy in achieving prolonged reductions in total serum bilirubin in neonates with nonhemolytic jaundice (7).
- Alloimmune hemolytic disease of the newborn (HDN) (1)
    - For correction of severe anemia and hyperbilirubinemia
    - In addition, in infants with alloimmune HDN, ET replaces antibody-coated neonatal red cells with antigen-negative red cells that should have normal in vivo survival and also removes free maternal antibody in plasma.
- Severe anemia with congestive cardiac failure or hypervolemia (1, 8)
- Polycythemia

Although partial exchange transfusion with crystalloid or colloid reduces the packed cell volume and hyperviscosity in neonates with polycythemia, there appears to be no evidence of long-term benefit from the procedure (9).

- Disseminated intravascular coagulation (2)
- Congenital leukemia (10)
- Metabolic toxins
  - Hyperammonemia (11)
  - Organic acidemia (12)
  - Lead poisoning (13)
- Drug overdose or toxicity (14, 15)
- Removal of antibodies and abnormal proteins (16, 17)
- Neonatal sepsis or malaria (18, 19)

C. Contraindications

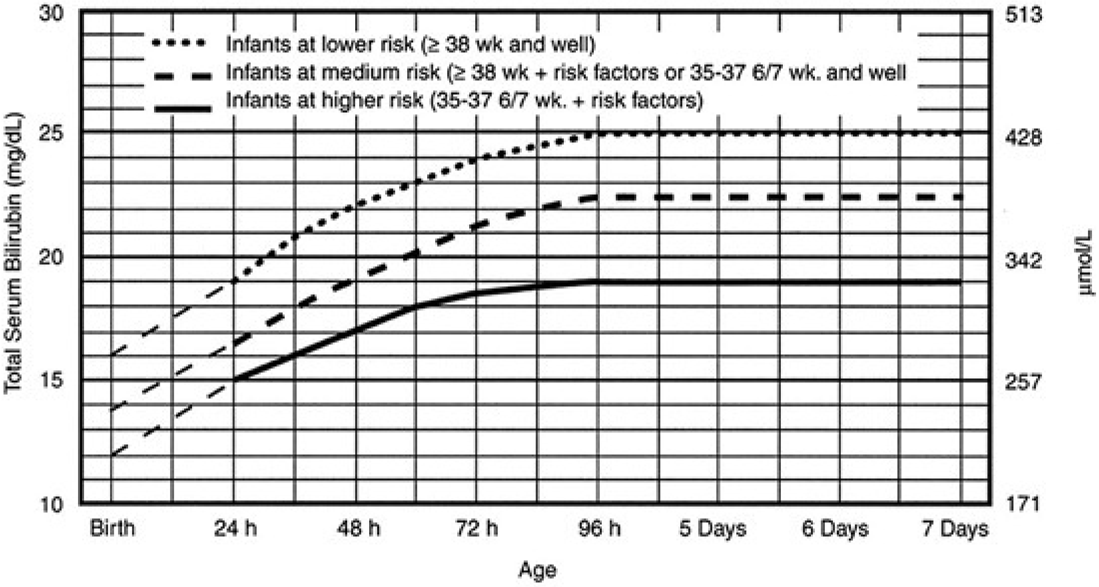
- When alternatives such as simple transfusion or phototherapy would be just as effective with less risk (7)
- When patient is unstable and the risk of the procedure outweighs the possible benefit

  In infants with severe anemia, with cardiac failure or hypervolemia, partial ET may be useful to stabilize the patient's condition before a complete or double-volume ET is performed.

- When a contraindication to placement of necessary lines outweighs indication for ET. Alternative access should be sought if ET is imperative (20).

D. Equipment

- Infant care center (see Chapter 2)
  - Automatic and manually controlled heat source
  - Temperature monitor
  - Cardiorespiratory monitor
  - Pulse oximeter for oxygen saturation monitoring
- Resuscitation equipment and medication (immediately available)
- Infant restraints
- Orogastric tube
- Suctioning equipment
- Equipment for central and peripheral vascular access
- Blood warmer and appropriate coils (see Precautions)



- The dashed lines for the first 24 hours indicate uncertainty due to a wide range of clinical circumstances and a range of responses to phototherapy.
- Immediate exchange transfusion is recommended if infant shows signs of acute bilirubin encephalopathy (hypertonia, arching, retrocollis, opisthotonos, fever, high pitched cry) or if TSB is ≥5 mg/dL (85 µmol/L) above these lines.
- Risk factors - isoimmune hemolytic disease, G6PD deficiency, asphyxia, significant lethargy, temperature instability, sepsis, acidosis.
- Measure serum albumin and calculate B/A ratio (See legend)
- Use total bilirubin. Do not subtract direct reacting or conjugated bilirubin
- If infant is well and 35-37 6/7 wk (median risk) can individualize TSB levels for exchange based on actual gestational age.

FIG. 42.1. Guidelines for exchange transfusion in infants 35 or more weeks gestation. (From American Academy of Pediatrics. Subcommittee on Hyperbilirubinemia. Clinical Practice Guideline. Management of hyperbilirubinemia in the newborn infant 35 or more weeks gestation. Pediatrics. 2004;114:297-316.)

- Sterile exchange transfusion equipment
    - Pre-assembled disposable set with special stopcock (Pharmaseal, Allegiance Healthcare Corporation, McGaw Park, IL, USA) or
    - Nonassembled
        - 10- or 20-mL syringes Use a smaller syringe if aliquot per pass is smaller.
        - Two three-way stopcocks with locking connections
        - Waste receptacle (empty IV bottle or bag)
        - IV connecting tubing
- Appropriate blood product
- Syringes and tubes for pre- and postexchange blood tests

E. Precautions

- Stabilize infant before initiating exchange procedure.
- Do not start exchange procedure until personnel are available for monitoring and as backup for other emergencies.
- Use blood product appropriate to clinical indication. Use freshest blood available, preferably <5 to 7 days.
- Check potassium level of donor blood if patient has hyperkalemia or renal compromise.
- Monitor infant closely during and after procedure.
- Do not rush procedure.
    - May necessitate repeat ET if efficacy is decreased by haste.
    - Stop or slow procedure if patient becomes unstable.

- Use only thermostatically controlled blood-warming device that has passed quality control for temperature and alarms. Be sure to review operating and safety procedures for specific blood warmer. Do not overheat blood, i.e., beyond 38Â°C.
- Do not apply excessive suction if it becomes difficult to draw blood from line. Reposition line or replace syringes, stopcocks, and any adapters connected to line.
- Leave anticoagulated, banked blood in line or clear line with heparinized saline if the procedure is interrupted.
- Clear line with heparinized saline if administering calcium.

F. Preparation for Total or Partial Exchange Transfusion

- Blood product and volume Blood Product
  - Communicate with blood bank or transfusion medicine specialist to determine most appropriate blood product for transfusion.
    - Plasma-reduced whole blood or packed red cells reconstituted with plasma, with a packed cell volume adjusted to 0.5 to 0.60, is suitable for ET to correct anemia and hyperbilirubinemia (1, 21, 22 and 23).
    - Blood may be anticoagulated with citrate phosphate dextrose (CPD or CPDA1) or heparin. Additive anticoagulant solutions are generally avoided (21, 22, 23 and 24). If only RBCs stored in additive solutions are available, the additive solution may be removed by washing or by centrifugation and removal of the supernatant solution, prior to reconstitution of the red cells with plasma.
    - Blood should be as fresh as possible (<7 days).
    - Irradiated blood is recommended for all ET, to prevent graft-versus-host disease. There is a significant increase in potassium concentration in stored irradiated units, so irradiation should be performed as close to the transfusion as possible (<24 hours).
    - Standard blood-bank screening is particularly important, including sickle-cell preparation, HIV, hepatitis B, and cytomegalovirus (CMV) (see Chapter 41).
    - Donor blood should be screened for G-6-PD deficiency and HbS in populations endemic for these conditions (25).
  - In presence of alloimmunization, e.g., Rh, ABO, special attention to compatibility testing is necessary (1).
    - If delivery of an infant with severe HDN is anticipated, O Rh-negative blood cross-matched against the mother may be prepared before the baby is born.
    - Donor blood prepared after the infant's birth should be negative for the antigen responsible for the hemolytic disease, and should be cross-matched against the infant.
    - In ABO HDN, the blood must be type O and either Rh-negative or Rh-compatible with the mother and the infant. The blood should be washed free of plasma or have a low titer of anti-A or anti-B antibodies. Type O cells with AB plasma may be more effective, but this results in two donor exposures per ET (26).
    - In Rh HDN, the blood should be Rh-negative, and may be O group or the same group as the infant.
  - In infants with polycythemia, the optimal dilutional fluid for a partial ET is isotonic saline rather than plasma or albumin (27).

Volume of Donor Blood Required

- Whenever possible, use no more than equivalent of one whole unit of blood for each procedure, to decrease donor exposure.
- Quantity needed for total procedure = volume for the actual ET plus volume for tubing dead space and blood warmer (usually 25 to 30 mL)
- Double-volume ET for removal of bilirubin, antibodies, etc.:

2 — infant's blood volume = 2— 80 - 120 mL/kg

    - Infant's blood volume in preterm infant < 100 to 120 mL/kg, in term infant < 80 to 85 mL/kg
    - Exchanges approximately 85% of infant's blood volume (Fig. 42.2)
  - Single volume ET: Exchanges approximately 60% of infant's blood volume (Fig. 42.2)
  - Partial ET for correction of severe anemia:

$$\text{Volume (mL)} = \frac{\text{infant's blood volume} \times (\text{Hb desired} - \text{Hb initial})}{\text{Hb of PRBC} - \text{Hb initial}}$$

  - Single-volume or partial ET for correction of polycythemia:

$$\text{Volume (mL)} = \frac{\text{infant's blood volume} \times \text{desired HCT change}}{\text{initial HCT}}$$

- Preparation of infant
  - Place infant on warmer with total accessibility and controlled environment. ET on small preterm infants may be performed in warm incubators, provided a sterile field can be maintained and lines are easily accessible.
  - Restrain infant suitably. Sedation and pain relief are not usually required. Conscious infants may suck on a pacifier during the procedure.

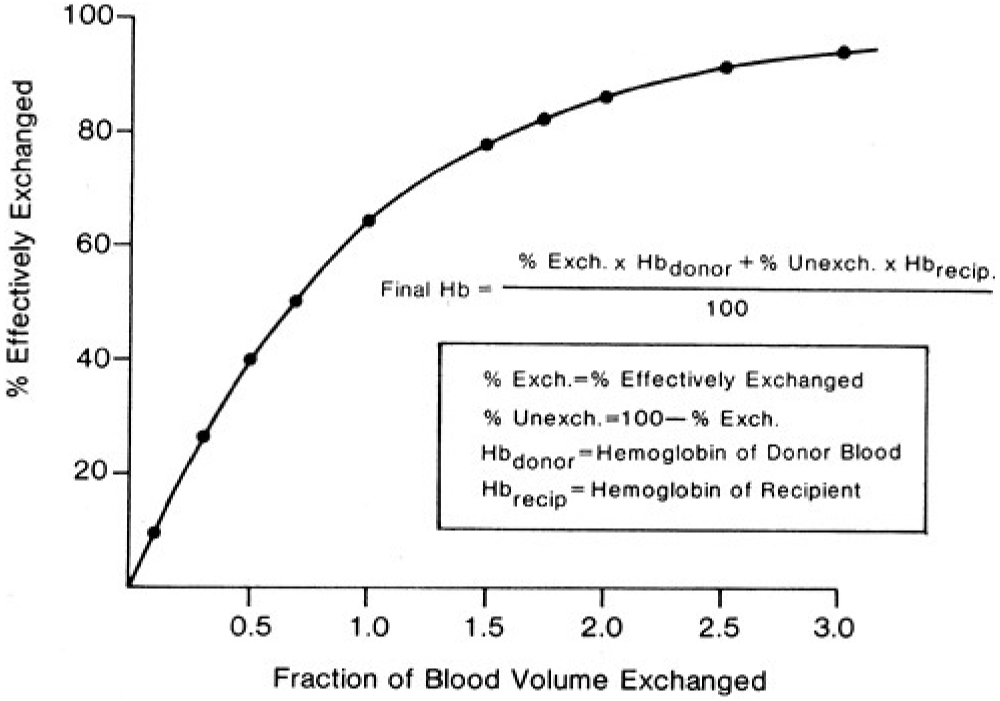


FIG. 42.2. Graph depicting the effectiveness of exchange transfusion against the fraction of blood volume exchanged. The formula permits the calculation of the final hemoglobin.

  - Connect physiologic monitors and establish baseline values (temperature, respiratory and heart rates, oxygenation)
  - Empty infant's stomach.
    - Do not feed for 4 hours prior to procedure, if possible.

    - Place orogastric tube and remove gastric contents; and leave on open drainage.
  - Start IV line for glucose and medication infusion:
    - If exchange procedure interrupts previous essential infusion rate
    - If prolonged lack of oral or parenteral glucose will lead to hypoglycemia
    - Extra IV line may be necessary for emergency medications.
  - Stabilize infant prior to starting exchange procedure; e.g., give packed-cell transfusion when severe hypovolemia and anemia are present, or modify ventilator or ambient oxygen when there is respiratory decompensation.
- Establish access for ET
  - Push pull technique: Central access usually through umbilical venous catheter.
  - Isovolumetric exchange with simultaneous infusion of donor blood through venous line and removal of baby's blood through arterial line. This technique may be better tolerated in sick or unstable neonates because there is less fluctuation of blood pressure and cerebral hemodynamics. The technique is also favored when only peripheral vascular access is available or preferred for various reasons (28, 29 and 30).
    - Infusion of donor blood may be through umbilical venous catheter or peripheral intravenous catheter.
    - Removal of baby's blood may be from umbilical arterial or venous catheter, or peripheral arterial catheter, usually a radial arterial line.
- Laboratory tests on infant's blood pre-exchange Tests are based on clinical indications.
  - Pre-exchange diagnostic studies. Note that diagnostic serologic tests on the infant, such as studies to evaluate unexplained hemolysis, antiviral antibody titers, metabolic screening, or genetic tests should be drawn prior to the ET.
  - Hemoglobin, hematocrit, platelets
  - Electrolytes, calcium, blood gas
  - Glucose
  - Bilirubin
  - Coagulation profile
- Prepare blood.
  - Verify identification of blood product (see Chapter 41).
    - Type and cross-match data
    - Expiration date
    - Donor and recipient identities
  - Attach blood administration set to blood-warmer tubing and to blood bag.
  - Allow blood to run through blood warmer.

G. Technique (See DVD for Animation of this Procedure)

Exchange Transfusion by Push Pull Technique through Special Stopcock with Preassembled Tray

- Read instructions provided by manufacturer carefully.
- Scrub as for major procedure. Wear mask, head cover, sterile gown, and gloves.
- Open preassembled equipment tray, using aseptic technique.
- Identify positions on special stopcock in clockwise rotation (Figs. 42.3 and 42.4). The direction that the handle is pointing indicates the port that is open to the syringe. The special stopcock allows clockwise rotation in the order used: (a) withdraw from patient; (b) clear to waste bag; (c) draw new blood; (d) inject into patient. Always rotate the handle in clockwise direction to follow the proper sequence, and keep connections tight.
  - Male adapter to umbilical or peripheral line
  - Female adapter to the extension tubing to which waste bag will be attached
  - Connect to blood tubing for attachment to blood-warmer coil.

  - Neutral off position in which additives may be administered through rubber stopper (180 degrees from waste-receptacle port)

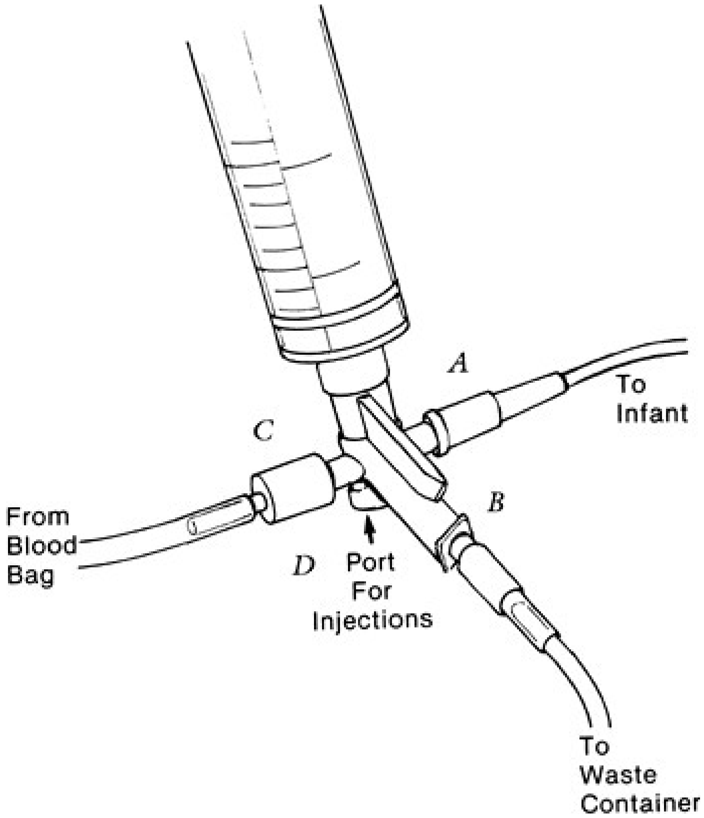


FIG. 42.3. Special four-way stopcock. A, male adapter to infant line; B, female adapter to waste container; C, attachment to blood tubing; D, off position (180 degrees from adapter to waste container), allowing injection through rubber-stoppered port below syringe. The stopcock is used in clockwise rotation when correctly assembled.

- Follow steps as provided by manufacturer to make all connections to blood and waste bags.
- With stopcock open to blood source, clear all air into syringe. Turn in clockwise direction 270 degrees and evacuate into waste.
- Turn stopcock to off and replace onto sterile field.
- Use pre-existing umbilical venous line or insert umbilical venous catheter, using sterile technique as described in Chapter 29 and attach spinal stopcock.
  - Consider CVP measurement, using pressure transducer, in unstable baby.
  - Place catheter in IVC and verify position by radiograph.
  - If catheter cannot be positioned in IVC, it may still be used cautiously in an emergency, when placed in the umbilical vein, if adequate blood return is obtained.

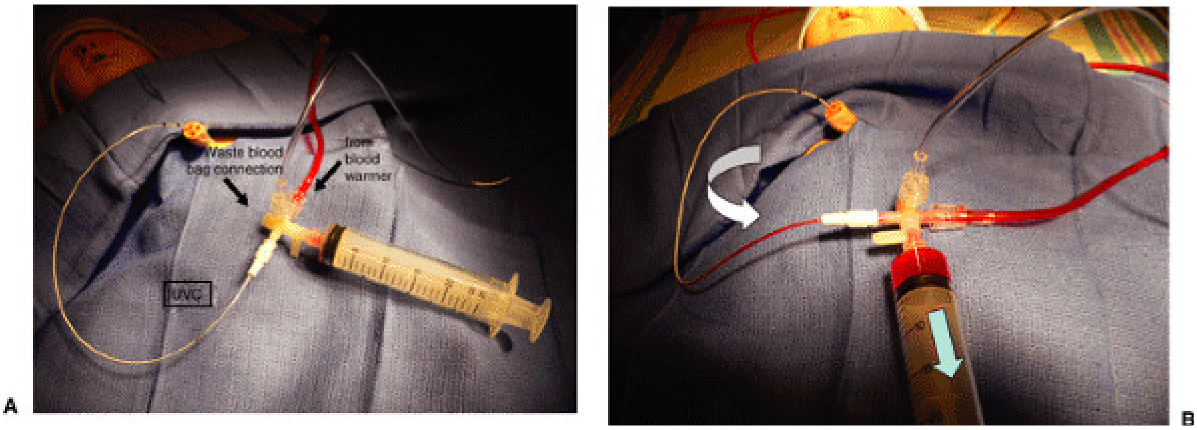


Fig. 42.4. A, B: ET using special four-way stopcock.

- Have an assistant document all vital signs, volumes, and other data on the exchange record.
- Check peripheral glucose levels every 30 to 60 minutes. Monitor cardiorespiratory status, continuous pulse oximetry. Determine blood gases as often as indicated by pre-existing clinical condition and stability.
- Draw blood for diagnostic studies
- Usual rate of removal and replacement of blood during the ET is aliquots of approximately 5 mL/kg over a 2- to 4-minute cycle.
- If infant is hypovolemic or has low CVP, start exchange with transfusion of aliquot (5 mL/kg) into catheter. If infant is hypervolemic or has high CVP, start by withdrawing precalculated aliquot.
- Remeasure CVP if indicated. Expect rise as plasma oncotic pressure increases, if CVP is low at start.
- Ensure that the stages of drawing and infusing blood from and into the infant are done slowly, taking at least a minute each to avoid fluctuations in blood pressure. Rapid fluctuations in arterial pressure in the push pull technique may be accompanied by changes in intracranial pressure (28, 31). Rapid withdrawal from the umbilical vein induces a negative pressure that may be transmitted to the mesenteric veins and contribute to the high incidence of ischemic bowel complications (32).
- Gently agitate the blood bag every 10 to 15 minutes to prevent red cell sedimentation, which may lead to exchange with relatively anemic blood towards the end of the exchange.
- Consider giving calcium supplement:
    - When hypocalcemia is documented
    - With symptoms or signs of hypocalcemia
        - Change in QTc interval
        - Agitation and tachycardia these symptoms are not reliably correlated with ionized calcium levels.

It is rarely necessary or advantageous to give calcium during an exchange if the infant is normocalcemic. When calcium is administered, the effect may last only a few minutes. Calcium will reverse the effect of the anticoagulant in the donor blood and may cause clotting of the line, so administration through a peripheral intravenous line is preferred. If calcium is given through an umbilical venous catheter, clear the line of donor blood prior to calcium administration with 0.9% NaCl. Give 1 mL of 10% calcium gluconate per kilogram body weight. Administer slowly, with careful observation of heart rate and rhythm. Clear line again with 0.9% NaCl.

- Perform calculated number of passes, until desired volume has been exchanged.

- Be sure there is adequate volume of donor blood remaining to infuse after last withdrawal, if a positive intravascular balance is desired.
- Clear umbilical line of banked blood and withdraw amount of infant's blood needed for laboratory testing, including re-cross-matching.
- Infuse IV fluids with 0.5 to 1 U heparin/mL of fluid through UVC if further ET are anticipated.
- Total duration for double-volume ET: 90 to 120 minutes.
- Document procedure in patient's hospital record.

Exchange Transfusion Using a Single Umbilical Line and Two Three-Way Stopcocks in Tandem

The principles and techniques for using either the special stopcock or two three-way stopcocks in tandem are the same. It is important to ensure that all junctions are tight to produce a closed, sterile system. It is also essential to understand the working positions of the stopcocks before starting the exchange.

- Scrub as for major procedure. Wear sterile gown and gloves.
- Attach stopcock and tubing in sequence (Fig. 42.5).
  - Proximal stopcock
    - Umbilical catheter
    - IV extension tubing to sterile waste container
  - Distal stopcock
    - Tubing from blood-warming coil
    - 10- or 20-mL syringe
- Clear lines of air bubbles.
- Start exchange record.

Follow steps of push pull technique until exchange is completed.

Exchange Transfusion by Isovolumetric Technique (Central or Peripheral Line)

- Scrub as for major procedure.
- Select two sites for line placement, and insert as per Section 5, Vascular Access.
  - Venous for infusion
    - Umbilical venous catheter (preferred)
    - Peripheral IV cannula that is at least 23 gauge
  - Arterial for removal
    - Umbilical artery catheter (preferred)
    - Peripheral, usually radial if infant's size permits
- Connect arterial line to three-way stopcock.
  - Use short, connecting IV tubing to extend peripheral line.
  - Attach additional connecting tubing to stopcock and place into sterile waste container.

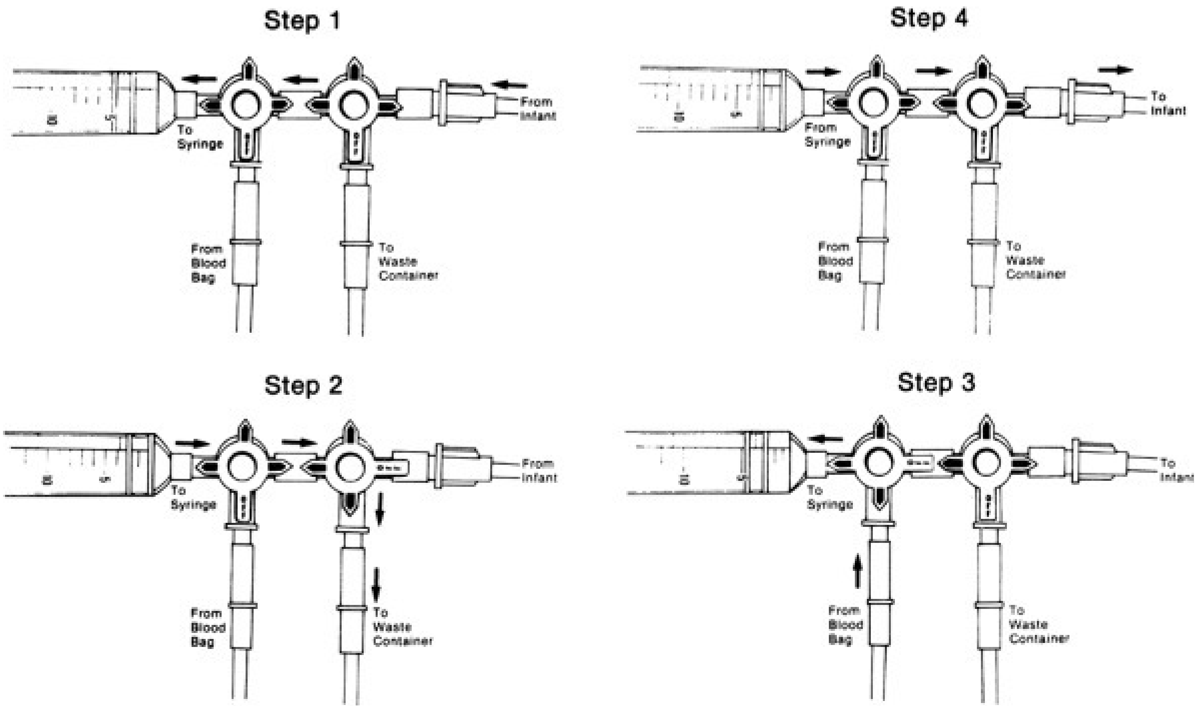

Step 1
To Syringe
From Infant
From Blood Bag
To Waste Container
Step 4
From Syringe
To Infant
From Blood Bag
To Waste Container
Step 2
To Syringe
From Infant
From Blood Bag
To Waste Container
Step 3
To Syringe
To Infant
From Blood Bag
To Waste Container

FIG. 42.5. Three-way stopcocks in tandem. Step 1: Stopcocks positioned for withdrawing blood from infant. Step 2: Stopcocks positioned for emptying withdrawn blood to waste container. Step 3: Stopcocks positioned for filling syringe from blood bag. Step 4: Stopcocks positioned for injecting blood into infant line.

        - Attach empty 3- to 10-mL syringe to stopcock, for withdrawal of blood.

          An additional stopcock may also be placed on this port so that a syringe of heparinized saline (5 U/mL) may be attached for use as needed. Be cautious about total volume infused.

    - Connect venous line to single, three-way stopcock, which in turn connects to empty 5- to 10-mL syringe and to blood-warming coil.
    - Start exchange transfusion record.
    - Withdraw and discard blood from arterial side at rate of 2 to 3 mL/kg/min, and infuse at same rate into venous side. Keep flow as steady as possible, and volumetrically equal for infusion and removal.
    - Intermittently, flush arterial line with heparinized saline to clear.

      The heparin solution remaining in tubing will be removed with next withdrawal, thus reducing significantly the total heparin dose actually received by the patient.

- Follow steps as for pushâ€“pull technique until exchange is complete.
- Total duration for isovolumetric ET: 45 to 60 minutes; may be longer in sick, unstable infants

H. Postexchange for All Techniques

- Continue to monitor vital signs closely for at least 4 to 6 hours.
- Rewrite orders; adjust any drug dosages as needed to compensate for removal by exchange (Table 42.1) (33, 34, 35).
- Keep infant NPO for at least 4 hours. Restart feeds cautiously if clinically stable. Monitor abdominal girth and bowel sounds every 3 to 4 hours for next 24 hours if exchange has been performed using umbilical vascular lines. Observe for signs of feeding intolerance.
- Monitor serum glucose levels every 2 to 4 hours for 24 hours.
- Repeat blood gases as often as clinically indicated.

TABLE 42.1 Hypothetical Drug Loss by Exchange Transfusion Calculated by First-Order Elimination from a Single Compartment (1 â€” e^{-V/V_d})

	Percent Loss	
Drug	**One Volume**	**Two Volume**
Amikacin	7.1	13.8
Ampicillin	7.7	14.7
Carbamazepine	3.7	7.2
Carbenicillin	5.6	10.9
Colistin	18.7	33.9
Diazepam	2.3	4.5
Digoxina	1.2	2.4
Furosemide	4.9	9.5
Gentamicin	5.2	10.1
Kanamycin	5.6	10.9
Methicillin	10.1	19.1
Oxacillin	19.6	35.4
Penicillin G (crystalline)	6.0	11.6
Penicillin G (procaine)	2.4	4.8
Phenobarbital	6.4	12.3
Phenytoin	3.1	6.2
Theophylline[a]	17.8	32.4
Tobramycin	10.3	19.6
Vancomycin	5.7	11.0

V, plasma volume exchanged in liters; V_d, apparent volume of distribution.

[a] Whole-blood volume used in calculation.

Source: From **Lackner TE**. Drug replacement following exchange transfusion. *J Pediatr*. 1982;100:813, with permission

- Measure serum ionized calcium levels and platelet counts in sick infants immediately after the ET and then as indicated.
- Repeat hemoglobin, hematocrit, and bilirubin measurements approximately 4 hours after exchange, and further as clinically indicated. A double-volume ET replaces 85% of the infant's blood volume, but eliminates only about 50% of the intravascular bilirubin. Equilibration of intra- and extravascular bilirubin, and continued breakdown of sensitized and newly formed red cells by persisting maternal antibody, results in a rebound of bilirubin levels following initial ET, and may necessitate repeated ET in severe HDN.

I. Complications

- Risk of death or permanent serious sequelae is estimated to be less than 1% in healthy infants, but as high as 12% in sick infants. There may be some uncertainty in ascribing adverse events to the ET procedure in infants who are already critically ill (36, 37, 38).
- Many of the adverse events are hematologic and biochemical laboratory abnormalities, which may be asymptomatic. The most common adverse effects noted during or soon after the ET, usually in infants who are preterm and/or sick include:
    - Apnea and/or bradycardia
    - Hypocalcemia
    - Thrombocytopenia (<50,000 in 10% of healthy infants, up to 67% of infants <32 weeks' gestational age)
    - Metabolic acidosis
    - Vascular spasm
- Complications reported from ET are related to the blood transfusion and to complications of vascular access (see Chapters 28, 29, 41).
- Potential complications include:
    - Metabolic: Hypocalcemia, hypo- or hyperglycemia, hyperkalemia
    - Cardiorespiratory: Apnea, bradycardia, hypotension, hypertension
    - Hematologic: Thrombocytopenia, dilutional coagulopathy, neutropenia, disseminated intravascular coagulation
    - Vascular catheter-related: Vasospasm, thrombosis, embolization (see Chapter 28 and 29)
    - Gastrointestinal: Feeding intolerance, ischemic injury, necrotizing enterocolitis
    - Infection: Omphalitis, septicemia

Acknowledgment

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43-Removal of Extra Digits and Skin Tags

Leah Greenspan Hodor
Khodayar Rais Bahrami

A. Indications

Removal of Nonfunctional Extra Digit

- Prevention of accidental avulsion or torsion around narrow base
- Cosmetic correction at parental request
- Prevention of traumatic amputation neuromas (1)

B. Contraindications

- Presence of illness in infant
- Presence of bleeding diathesis

  This is an elective procedure that is painful when the clamp is applied. To prevent accidental avulsion of appendage if extra digit on a narrow base were to become entangled, apply a soft dressing or adhesive bandage until infant is stable enough for removal.

- Presence of any other hand anomaly when further surgical correction may be necessary (2)
- Base of extra digit >5 to 6 mm in width
- Bone crossing the isthmus between extra digit and hand

C. Equipment

- Iodophor antiseptic solution and swabs
- Straight mosquito hemostat
- Surgical silk suture, 3-0 or 4-0
- Fine or delicate scissors
- Adhesive bandage

D. Precautions

- Perform procedure only on stable, healthy infant.
- Consider surgical evaluation for any questionable digit:
  - When base is >5 to 6 mm in width
  - When extra digit is on radial side of hand

  - When clamping will not crush base to a thin, translucent layer indicative of hemostasis after excision
  - When there appears to be a joint at the base
  - When bony structures are present in the digit as confirmed by radiography (3)
- Apply hemostat to base of extra digit prior to placing ligature.
  - Allows closer amputation without residual bump
  - Allows faster autoamputation or removal of most of digit within a few hours

E. Technique

Removal of Nonfunctional Digit (Fig. 43.1)

- Cleanse digit and the surrounding skin with iodophor antiseptic. Allow to dry.
- Clamp hemostat as close to the base of extra digit as possible but without drawing up extra skin (Fig. 43.2A).
- Tightly tie suture around digit between hemostat and hand.
- Keep clamp in place until digit turns white for at least 5 minutes.
- Using as a cutting guide the edge of the hemostat farther from the hand, excise the digit (Fig. 43.2B).
- Remove hemostat and observe for hemostasis, leaving ligature in place. If there is any bleeding, reapply hemostat and ligature.
- Cover with an adhesive bandage until residual stump autoamputates.

Removal of Skin Tags (Fig. 43.3)

The removal of small skin tags follows essentially the same technique as for extra digits: Clamp close to base of lesion to achieve hemostasis, and apply ligature between hemostat and normal area. If the lesions are large or in critical areas, removal is best delayed beyond the neonatal period. Consider other diagnoses associated with skin tags (4).

F. Complications

- Hemorrhage
  - Failure to achieve complete hemostasis prior to excision
  - Loosening of ligature before blood supply is retracted
- Infection
- Inappropriate removal of digit in presence of related anomalies

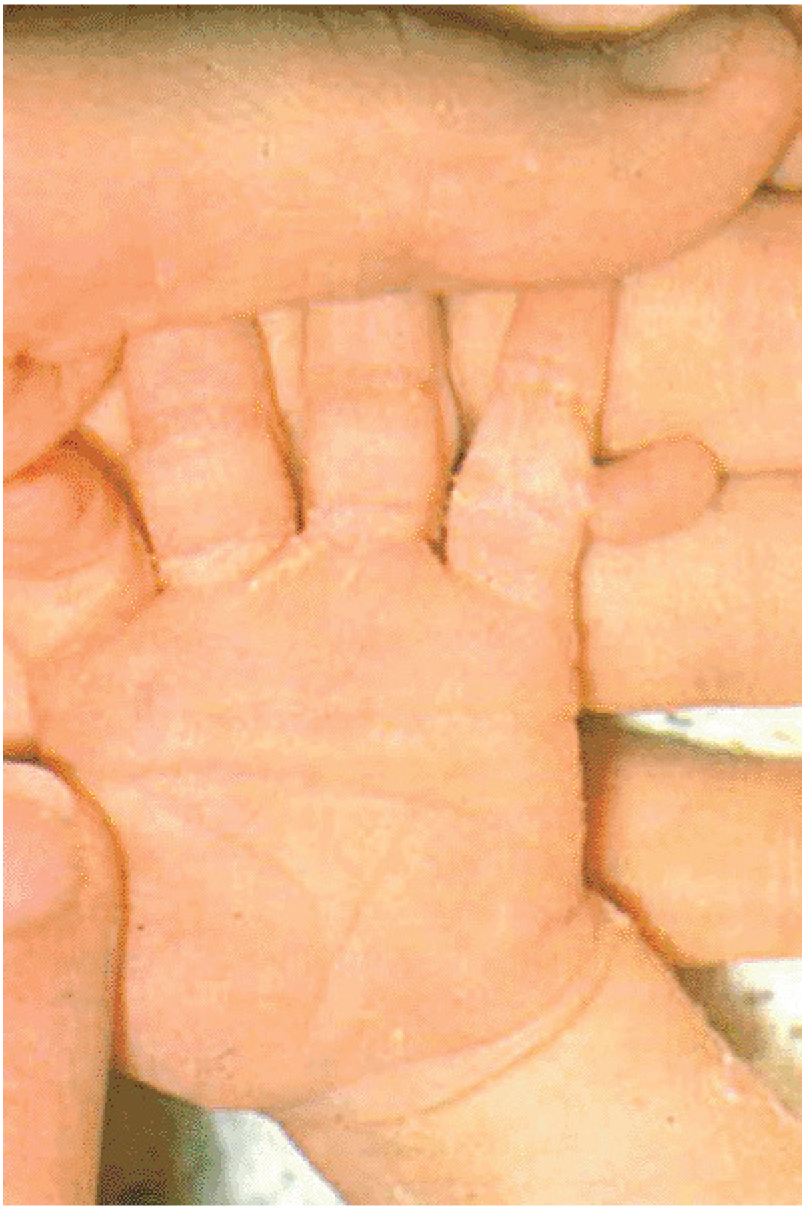

FIG. 43.1. Nonfunctional extra digit on ulnar side of left hand.

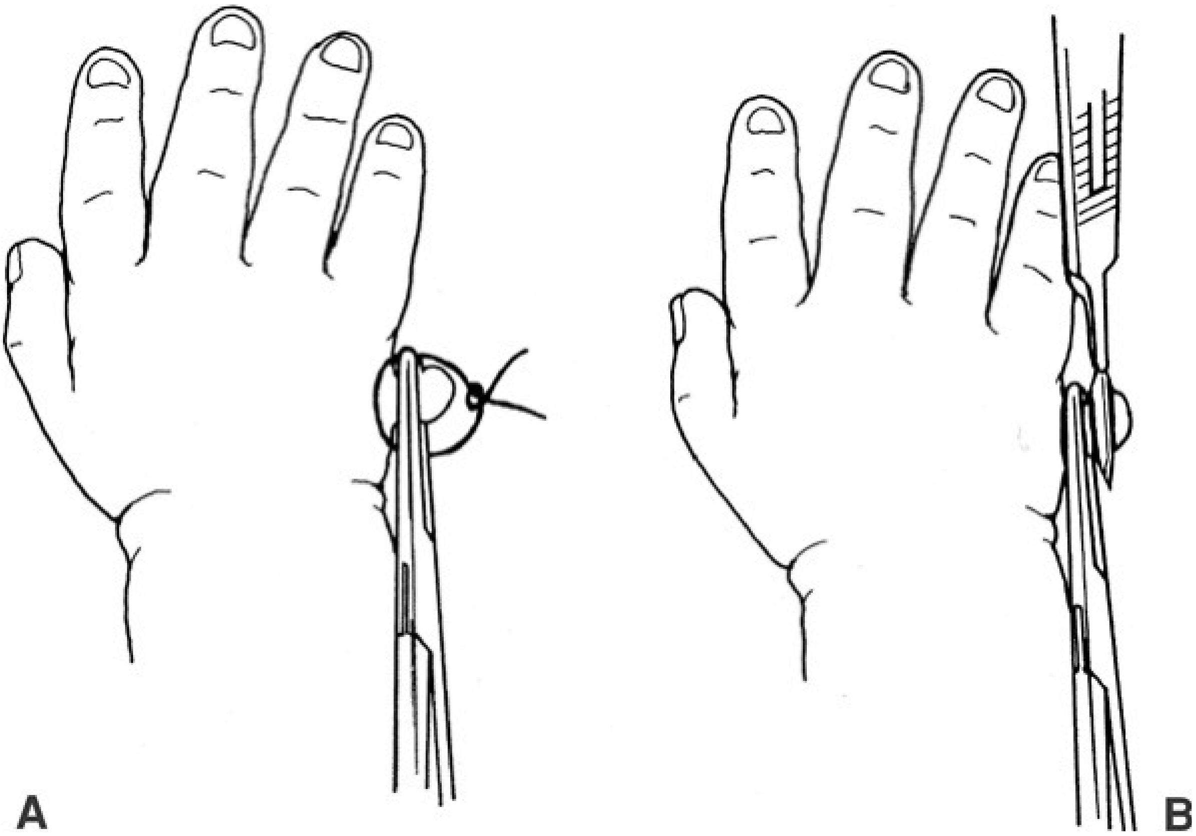

FIG. 43.2. A: Place fine hemostat as close to base of extra digit as possible, and firmly secure ligature between clamp and hand. B: After finger turns white, excise digit tag outside hemostat, leaving ligature in place for autoamputation of residual stump.

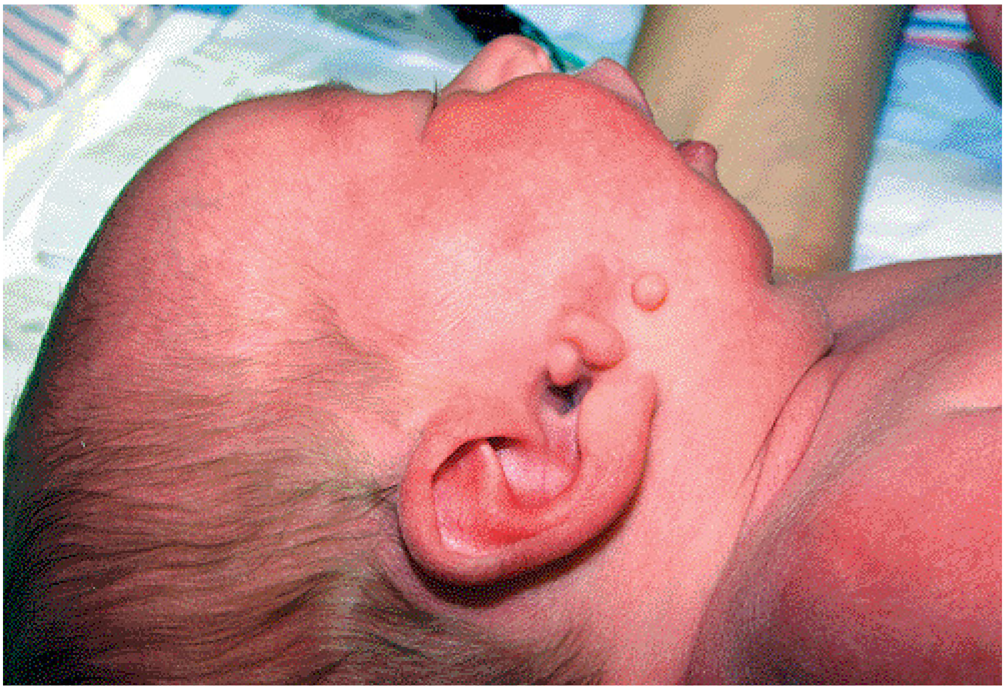

FIG. 43.3. Skin tags of right ear and cheek. Removal of tags this large requires surgical excision rather than ligation for best result and may be associated with other malformations.

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44-Circumcision

Mhairi G. MacDonald

A. Indications

Newborn male circumcision, one of the oldest formally recorded surgical procedures, remains controversial (1,2 and 3). Many physicians and lay people consider circumcision routine, but complications, although relatively rare, can be severe. Therefore, despite the perceived simplicity of the procedure, meticulous attention to anatomic landmarks, wound care, and follow-up is necessary.

A large French study compared the cost-effectiveness of circumcision and topical steroids as treatments for phimosis. The study concluded that topical pharmacologic treatment is effective in approximately 85% of patients, avoids the disadvantages, trauma, and potential complications of circumcision, and could reduce costs by 75% (4).

B. Contraindications

- Age <1 day (i.e., before complete physical adaptation to extrauterine life has occurred)
- Any current illness
- Prematurity (<37 weeks' gestation)
- Bleeding diathesis or family history of bleeding disorder
- Abnormality of urethra or penile shaft (foreskin may be essential for later reconstruction [e.g., hypospadias, chordee, very small penis])
- Local infection
- Lack of truly â€œinformed parental consent (see Chapter 1)

C. Equipment

- Necessary for all methods

Sterile

- Gown and gloves
- Cup with antiseptic
- 4x4-in gauze pads
- Small, flexible, blunt probe
- Two straight mosquito hemostats

- Large, straight hemostat
- Tissue scissors

Nonsterile

- Materials for restraint

- Optional equipment
    - Local anesthetic: 1% lidocaine hydrochloride without epinephrine in a tuberculin syringe with a 1.2-cm x 27-gauge needle

      Circumcision of neonates has frequently been used as a model to study the response of the newborn to pain (see Chapter 5). However, until recently, neonatal circumcision has been performed without anesthesia. Since the initial report by Kirya and Werthmann in 1978 (5), there have been reports of several controlled studies that have concluded that the use of dorsal penile nerve block is both effective and safe (5,6,7,8,9,10,11, and 12).

      The effectiveness of EMLA (eutectic mixture of local anesthetics; lidocaine and prilocaine, Astra Pharma) 5% cream has also been studied (13,14 and 15). Conclusions from meta-analysis of data from refs. (12,13 and 14) led to the conclusion that EMLA cannot be recommended over other analgesic techniques with proven efficacy, such as regional nerve block with lidocaine. However, current data provide sufficient evidence to recommend routine use of EMLA for neonatal circumcision pain in settings in which no analgesics are routinely administered (15).

    - Sterile fine-tipped marking pen
    - Sterile gauze impregnated with petroleum jelly (e.g., Vaseline)
- Additional equipment for use with Gomco clamp

  All equipment is sterile.

    - Gomco circumcision clamp (Gomco Surgical Manufacturing Corp., Buffalo, NY, USA) (16), size 1 to 2 cm for average newborn glans (size range 1 to 3.5 cm)

      Be sure to use a size that is large enough to protect the glans (17).

    - 11 scalpel blade and holder
    - A small safety pin
- Additional equipment for use with Plastibell

  All equipment is sterile.

    - Plastibell plastic cone (Hollister, Libertyville, IL, USA); available in presterilized packs; size range based on size of glans penis: 1.1, 1.3, and 1.5 cm. A linen suture is included in the pack (Fig. 44.1).

      When selecting size, make sure that it is not so large that it allows proximal migration of the bell and excessive loss of penile skin nor so small that it could impair penile circulation.

    - Scissors capable of cutting through plastic

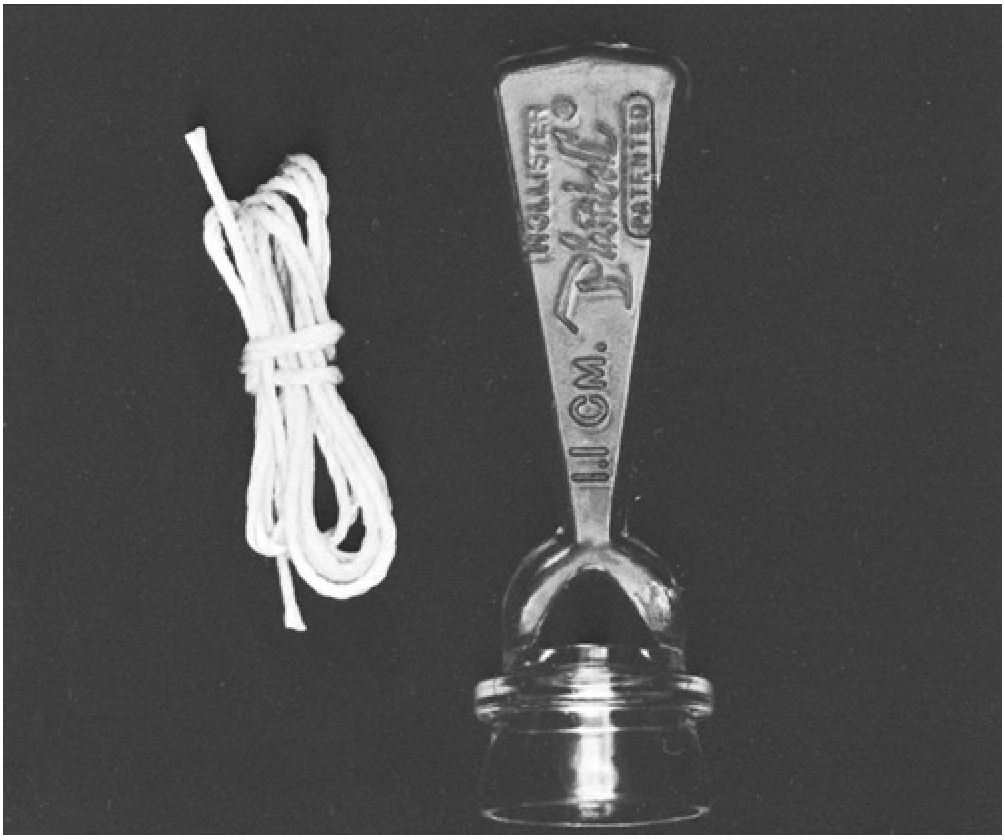

FIG. 44.1. Plastibell with linen suture.

D. Precautions

- Obtain fully informed consent (see Chapter 1).
    - Explain expected course of circumcision to parents. When Plastibell is used, parents should be told to call their physician if ring has not fallen off within 10 days (18).
    - Be aware of laws pertaining to ritual circumcision (e.g., Jewish brit milah) (1,19,20) and the complications of the practice of orally suctioning the blood after cutting the foreskin (oral metzitzah) (21).
- Never circumcise at time of delivery. Circumcise long enough before discharge to allow adequate wound observation.
- Do not use local anesthetic containing epinephrine.
- Specifically locate coronal sulcus and urethral meatus.
- Make sure that inner epithelium is completely separated from glans penis and that prepuce can be retracted to visualize entire circumference of coronal sulcus.
- Never use electrocautery.
- Do not use circumferential dressing.
- Recheck wound prior to discharging patient and 1 to 2 weeks after circumcision. Residual skin should retract completely, and entire coronal sulcus must be visible to avoid postcircumcision adhesions, the most common complication.

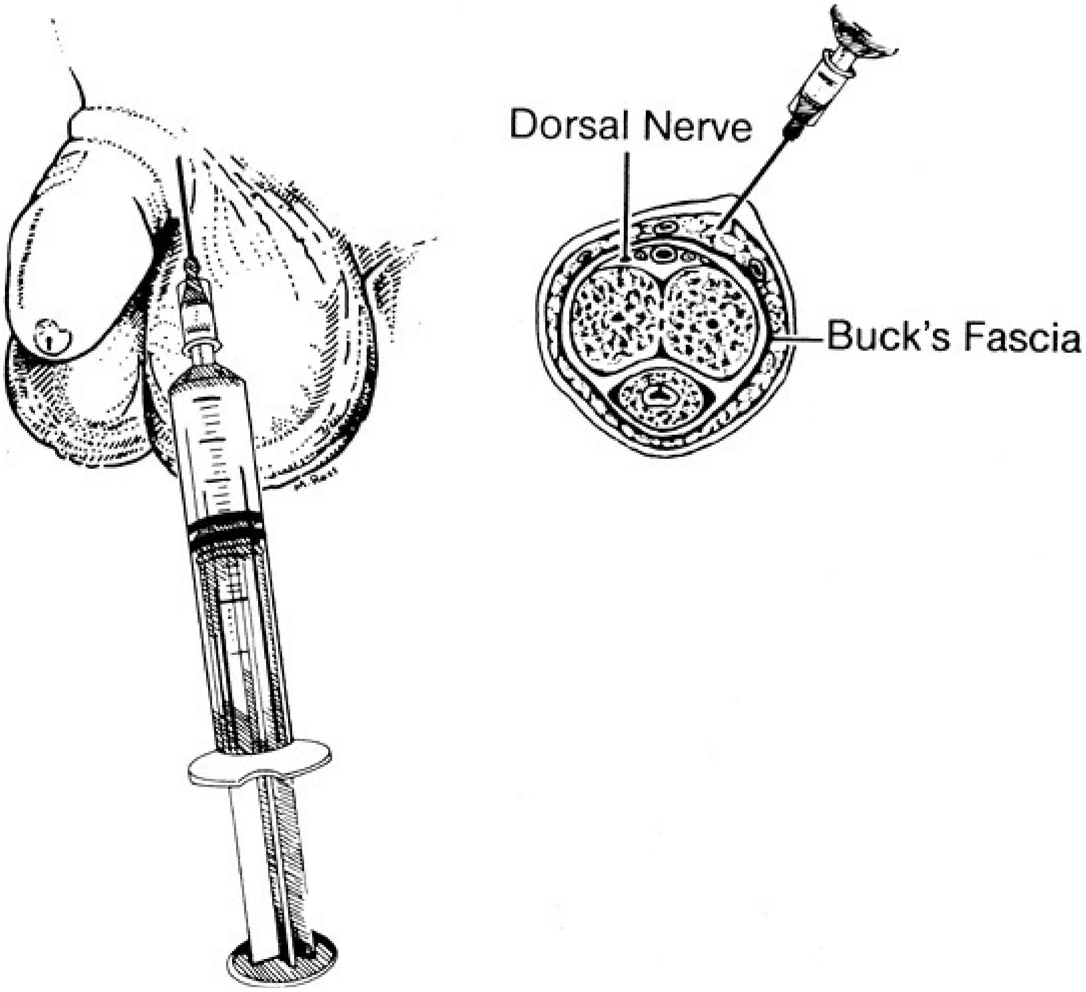

FIG. 44.2. Penis is stabilized at angle of 20 to 25 degrees from midline. The formation of a lidocaine ring is shown (see text).

E. Technique

A complete description of formal surgical excision has been excluded from this edition because of the requirement to use sutures and the associated increased risk of bleeding compared with methods that involve crushing of tissue.

Ritual circumcisions are most commonly performed using a Mogen clamp. The method involves no dorsal incision or sutures (22); however, because the glans is not visible at the time of excision of the prepuce, there is potential for damage to the glans and urethra.

- Immobilize infant in supine position.
- Put on cap and mask.
- Scrub as for major procedure.
- Put on gown and gloves.
- Prepare skin with antiseptic, and drape.
- Perform penile dorsal nerve block if desired.
    - Be familiar with anatomy of dorsal nerves of penis (Fig. 44.2) (5).

      Although only the two dorsal penile nerves are targeted by the injection of lidocaine, the ventral penile nerve is also blocked by infiltration through the subcutaneous tissue. Some have advocated additional anesthesia ventrally, blocking the perineal nerves (a branch of the pudendal nerve) (23).

- Identify dorsal nerve roots at 10 o'clock and 2 o'clock positions.
- Identify by palpation the symphysis pubis and corpora cavernosa at the penile base.
- Estimate depth of pubic bone from penile base to indicate necessary depth of injection (should not exceed 0.5 cm).

  Although the ideal area for infiltration corresponds to the 2 and 10 o'clock positions, 1 cm distal to the penile base, if the base is buried in pubic fat, the injection must be done at the junction of pubic and pelvic skin.

- Stabilize organ, with gentle traction, at angle of 20 to 25 degrees from midline.
- Pierce skin over one of dorsal nerves at penile root, and advance carefully posteromedially (0.25 to 0.5 cm) (Fig. 44.2) into subcutaneous tissue to avoid lodging in the erectile tissue.

  After entering skin, needle should not meet resistance and tip should remain freely movable. If the tip of the needle is not freely mobile, it is probably embedded in the corpora cavernosum beneath the dorsal nerve and should be withdrawn slightly.

- Aspirate to rule out intravascular position.
- Slowly infiltrate area with 0.2 to 0.4 mL of lidocaine (never infiltrate as needle is advanced or withdrawn).

  Arnett et al. (24) have reported good results using 0.2 mL of lidocaine.

- Repeat procedure at other dorsolateral position.

  After infiltration, a small lidocaine ring forms (Fig. 44.2). The swelling is minimal and does not interfere with the circumcision procedure.

- Wait 3 to 5 minutes for analgesia.

  Analgesia is usually obtained after 3 minutes and typically disappears within 20 to 30 minutes. However, there is individual variation, and testing of the prepuce with a hemostat is suggested prior to dissection.

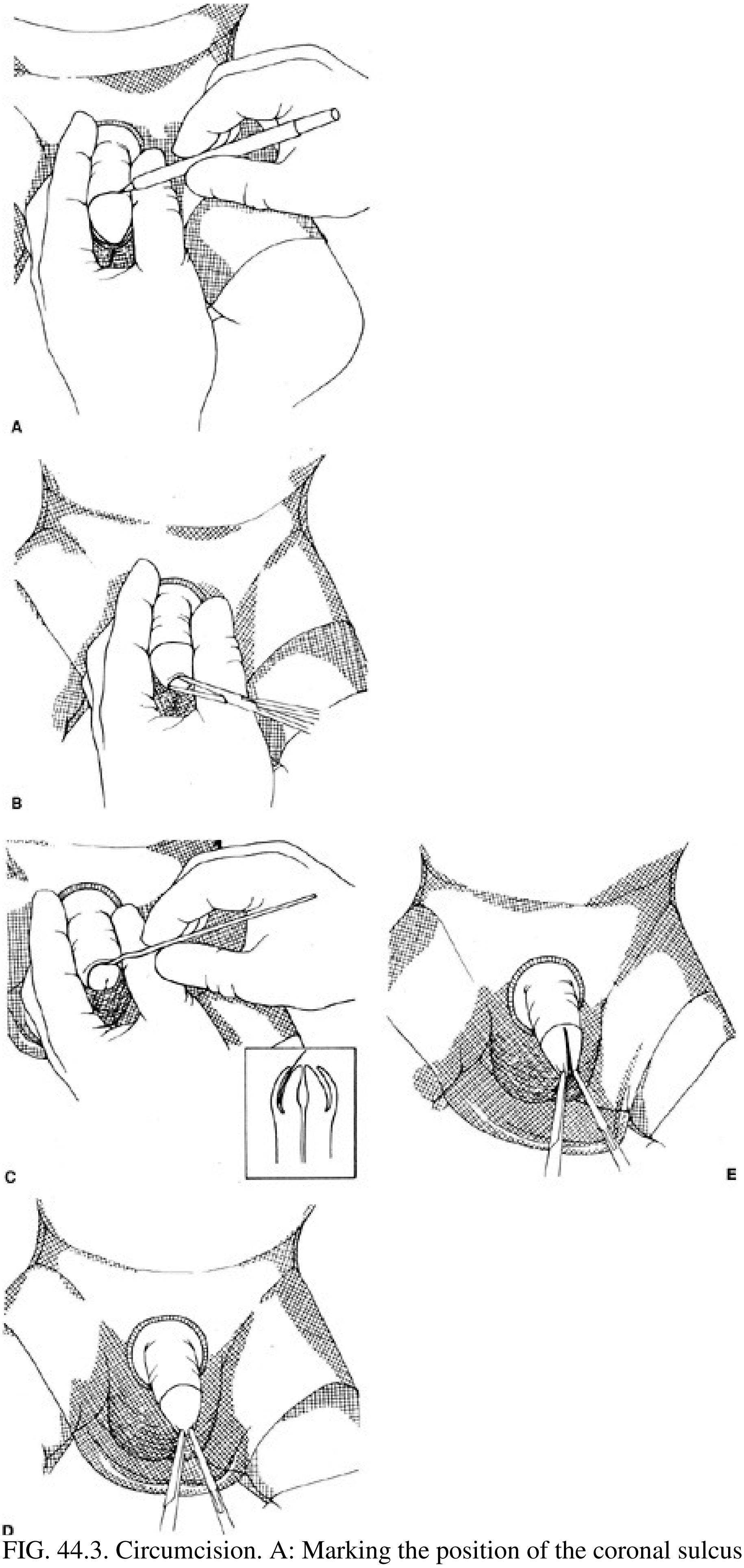

FIG. 44.3. Circumcision. A: Marking the position of the coronal sulcus. B: Dilating the

preputial ring. C: Separating the prepuce from the glans penis. D: Grasping the prepuce with mosquito hemostats in preparation for the dorsal slit procedure. E: Dorsal slit.

- Locate coronal sulcus (Fig. 44.3A). Marking the position of the sulcus with ink on the skin of the penile shaft, prior to the procedure, is helpful in demarcating this vital landmark.
- Use mosquito hemostat to dilate preputial ring (Fig. 44.3B).
- Use blunt probe to separate inner epithelium of prepuce from glans penis (Fig. 44.3C).

  Failure to do this completely may result in concealed penis (see G.3.c and G.13).

- Perform dorsal slit if desired.

  This step is not mandatory as long as there is adequate separation of the glans from the prepuce.

  - Grasp rim of prepuce on dorsal aspect with mosquito hemostats, approximately 2 to 4 mm apart (Fig. 44.3D).
  - Visualize urethra.
  - Place lower blade of large, straight hemostat between prepuce and glans to within 3 to 4 mm of corona, making sure to avoid urethra.
  - Close hemostat for 5 to 10 seconds to crush foreskin in dorsal midline.
  - Use tissue scissors to cut prepuce along crush line (Fig. 44.3E).
  - Check that prepuce is freed from entire surface of glans. Complete separation if necessary.
- Complete circumcision using method of choice.
  - Use of circumcision clamp
    - Check clamp to ensure that all parts are present, fit well, and are in good working order.
    - Assemble clamp, ensuring that yolk (arm) articulates correctly with baseplate.
    - Draw prepuce backward gently to expose entire glans penis.
    - Break down all residual adhesions, and observe position of meatus. If meatus is abnormal, cease at this point.
    - Sponge glans dry with gauze swabs.
    - Select stud (bell) of adequate size (see C), and place over glans (Fig. 44.4A).
    - Pull prepuce over stud.
      - Approximate edge of dorsal slit. (A sterile safety pin may be used.)
      - Observe amount of skin remaining under baseplate for accuracy.

        Proper placement of prepuce over stud is essential. Pulling too taut may lead to removal of excessive penile skin. Insufficient tension may lead to incomplete circumcision.

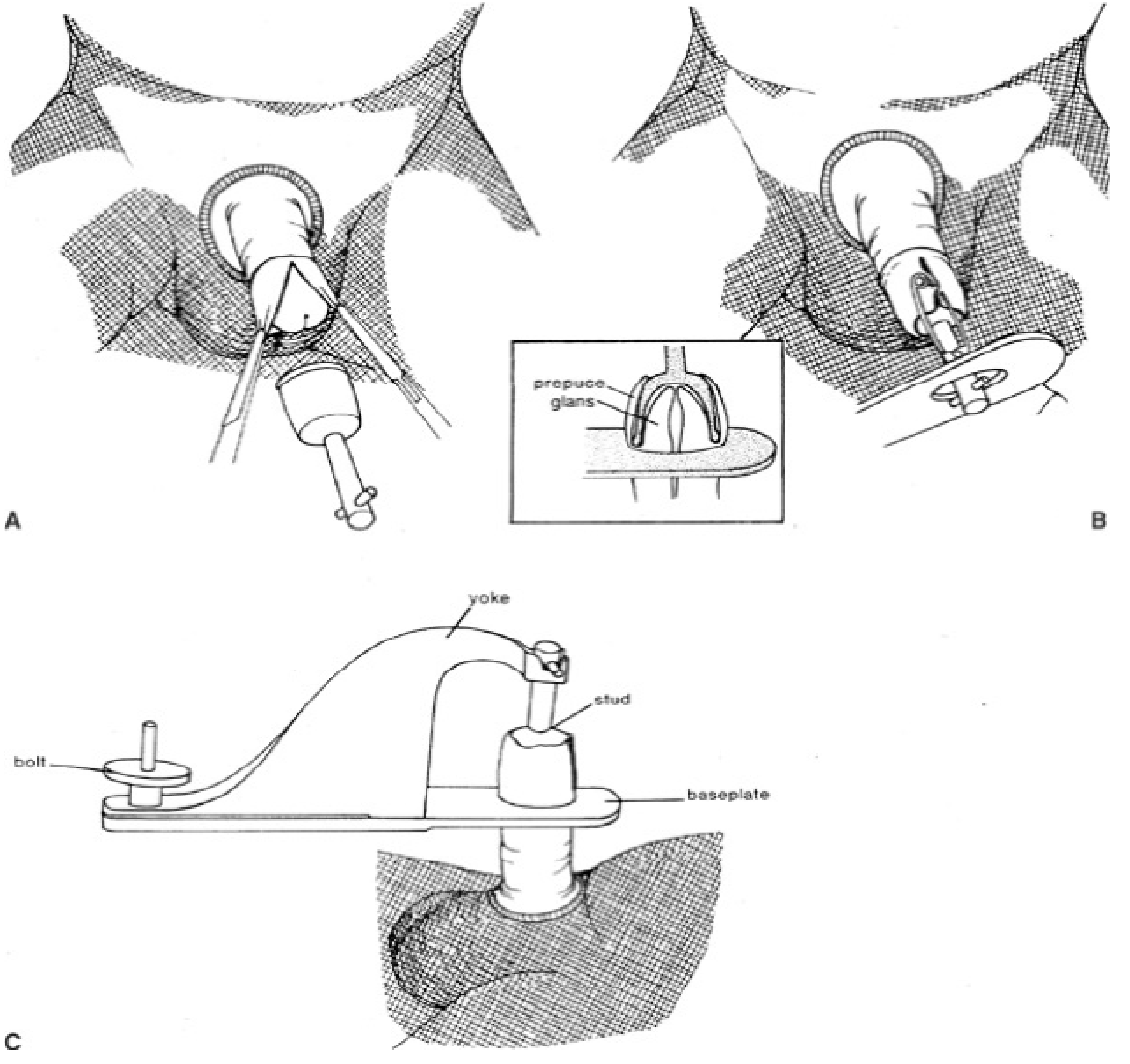
A
prepuce
glans
B
yoke
stud
bolt
baseplate
C

FIG. 44.4. Circumcision with a Gomco clamp. A: Placing the stud over the glans. B: Placing the baseplate of the clamp over the stud until the stud engages with the baseplate (inset). C: Gomco clamp in position for circumcision.

- Place baseplate of clamp over stud (with pin perpendicular to shaft of penis) so that prepuce is sandwiched between them (Fig. 44.4B).
- Continue to pull upward on stud until entire prepuce is drawn through baseplate and stud engages with baseplate.
- Hook yoke (arm) of clamp under side arms on shaft of stud and bolt firmly to baseplate, after checking position of prepuce between stud and baseplate (Fig. 44.4C).
- Remove safety pin.
- Wait 10 minutes.

Hemostasis is produced by pressure between baseplate and rim of stud. If the clamp is removed before 10 minutes has elapsed, wound edge hemostasis may be inadequate. If significant bleeding occurs during the procedure, remove the device and search for bleeding vesselâ€”avoid blindly placing sutures.

- Remove prepuce with scalpel held parallel to and flush with upper surface of baseplate. Never use electrocautery; however, use of an ultrasound dissection scalpel has been described as a safe alternative to electrocautery (25).
- Loosen bolt on clamp and remove.
- Optional: Dress with loose, noncircumferential sterile gauze impregnated with Vaseline.

Gough and Lawton (26) have shown that the addition of tincture of benzoin to the dressing adversely affected wound healing and the addition of topical antibiotic did not produce better results than those achieved with ordinary paraffin gauze.

- Apply tight diaper for 1 hour.
- For 24 hours after circumcision, check (or instruct parents to check) for bleeding, excessive swelling, and difficulty voiding.
- Until circumcised area is completely healed, do not immerse; give sponge bath.

Use of Plastibell

1.Follow Steps 3 to 5 of E.11.a.

2.Select bell of correct size (see C).

- Cone should fit snugly without pressure on glans
- Grooved rim of bell should be just distal to apex of dorsal slit.

3.If necessary, cut small segment out of cone so that it clears frenulum.

4.Hold prepuce firmly in place over cone (Fig. 44.5A).

5.Tie suture tightly around rim of bell so that prepuce is firmly compressed into groove.

6.Trim prepuce distal to ligature with tissue scissors. Use outer rim of cone as guide.

7.Break off cone handle. Tissue beneath ligature will atrophy and separate from bell in 5 to 8 days (maximum 10 to 12 days) (Fig. 44.5B).

8.Observe and care for circumcision as in Steps 17 and 18 of Gomco clamp (E.11.a).

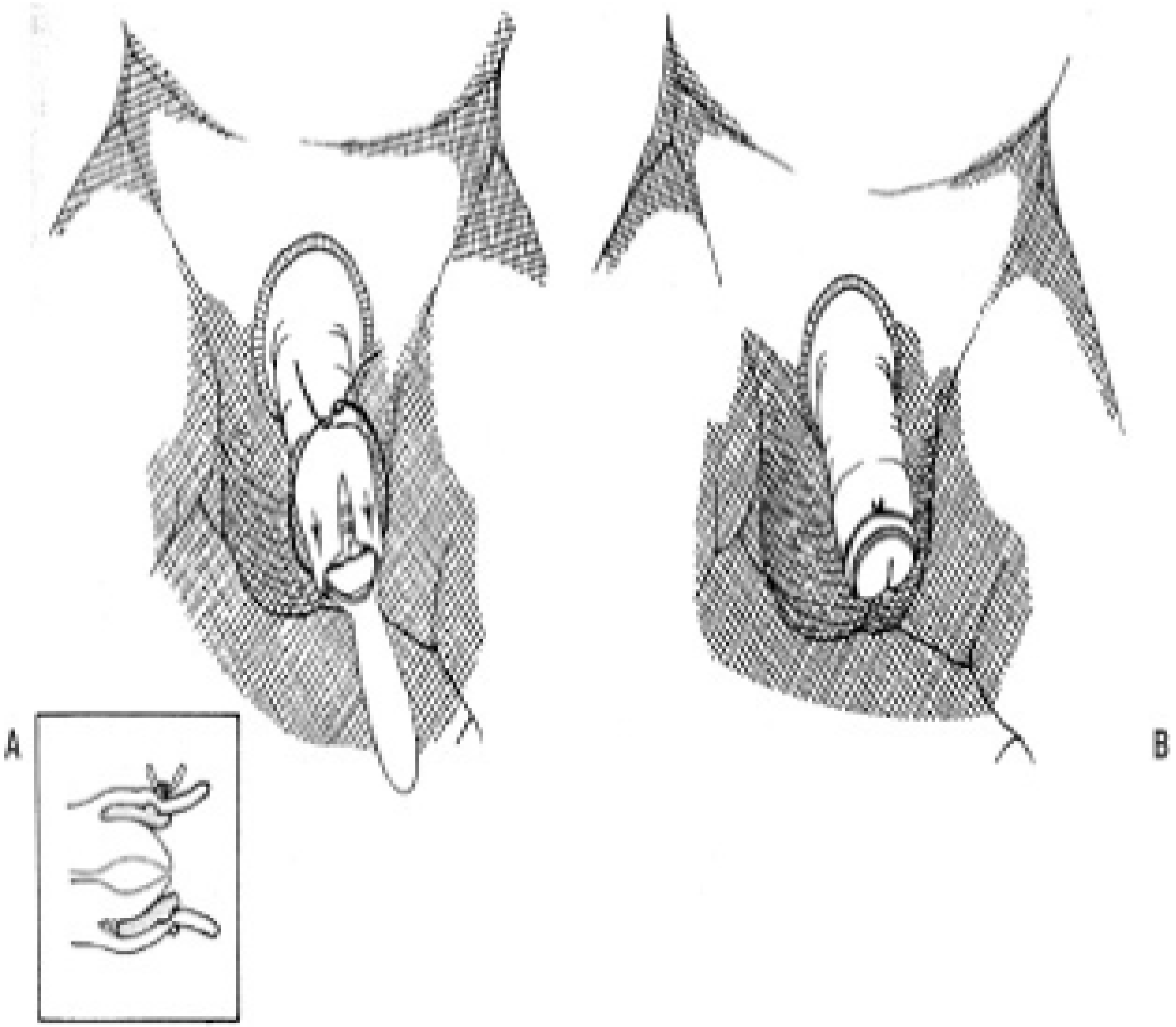

FIG. 44.5. Circumcision with a Plastibell. A: The prepuce is pulled forward onto the bell. Inset: The prepuce is compressed into the groove by the circumferential suture. B: Appearance of the completed circumcision.

F. Management of Postoperative Bleeding

Postoperative bleeding usually stems from inadequate hemostasis (e.g., unrecognized neonatal hepatitis [27] or hereditary clotting disorders). Rarely, anomalous vessels are responsible.

Continuous Ooze

- Apply manual pressure for 5 to 10 minutes.

  Check that the string on the Plastibell is in place and is sufficiently tight.

- Assess bleeding site. If continued oozing:
  - Apply topical thrombin (Thrombostat) on absorbable gelatin sponge (Gelfoam) or oxidized cellulose (Oxycel, Surgicel); do not use circumferential dressing.
  - Silver nitrate and epinephrine have also been used topically to control bleeding. To avoid local ischemia or systemic effects, do not exceed a 1:100,000 concentration of epinephrine.

Active Hemorrhage or Uncontrolled Ooze

- Surgical assessmentâ€"ligation of bleeding vessel
- Consider underlying coagulopathy.

G. Complications (Fig. 44.6A-D)

The overall incidence of complications associated with circumcision ranges from approximately 0.2% to 7% (28,29 and 30).

- Hemorrhage (26,27,28,29,30, and 31)
- Infection (32,33, 34,35, 36, and 37)

  More common with the Plastibell. Most are mild and respond to wet to dry dressings and Sitz baths, but fatalities have been reported (35).

  - Local (5,32,33)
  - Systemic (34,36)
  - Necrotizing fasciitis (37)
- Incomplete circumcision (most common complication) (38,39 and 40)
  - Phimosis (40)
  - Skin bridge between penile shaft and glans (commonly due to inadequate skin removal and failure to visualize the corona on follow-up examination) (40,41)
  - Concealed penis (see also G.13) (30,40,42,43 and 44)
- Trauma
  - Urethral laceration during dorsal slit procedure (avoided by keeping urethra in view at all times during the procedure)
  - Loss of penis (most commonly due to injuries related to cautery) (45,46)/amputation of glans (17)
  - Hypospadias/epispadias (47)
  - Cyanosis/necrosis of glans penis caused by overly tight Plastibell, misplaced sutures, or overtight circumferential bandage (30,40,48)
  - Urethrocutaneous fistula associated with use of Gomco clamp or Plastibell (most commonly caused by using a Plastibell or clamp of incorrect size or failure to recognize congenital megaloureter) (42,49,50)
- Urinary retention
  - Tight (or occlusive) dressing or glanular prolapse through ring of Plastibell (32,40,52,53 and 54)
  - Meatal stenosis resulting from urethral meatitis (5,40)
- Inflammation/ulceration of meatus (1,5,54,55,56,57, and 58)
- Circumcision of hypospadias (40,52)
- Chordee (40); most commonly is the result of dense ventral scarring from inflammation; may be due to removal of excess skin from shaft or secondary to a skin bridge
- Inclusion cyst of prepuce (52)
- Lymphedema (40,52,59)
- Venous stasis (60)
- Displacement with lodging of Plastibell around penile shaft or glans penis (18,61,62 and 63)
- Death
  - Anesthetic (1,63,64)
  - Infection (65)
- Wound separation/removal of excess skin (Fig. 44.6) (30,52,61,66)

Buried penis is usually the result of inappropriate circumcision in a chubby baby with a small or concealed penis. Excessive removal of skin should be treated with application of antiseptic (iodophor) daily and not with grafting or burying the penis in scrotum. The skin will grow back.

- Recurrence of pneumothorax (67)
- Reaction to epinephrine used to control bleeding (68)
    - Tachycardia
    - Local vasospasm (may lead to necrosis of the glans)
- Complications due to local anesthetic
    - Methemoglobinemia has been reported following exposure to prilocaine, procaine, benzocaine, and lidocaine (69).
    - Hematoma (70); those reported in neonates have resolved spontaneously.
    - Seizures (71)
- Mechanical problems with Gomco clamp (72)
    - Loss of a part
    - Warping of the plate after multiple use
    - Breakage of arm during tightening
    - Grooves and nicks in bell at junction of bell and plate

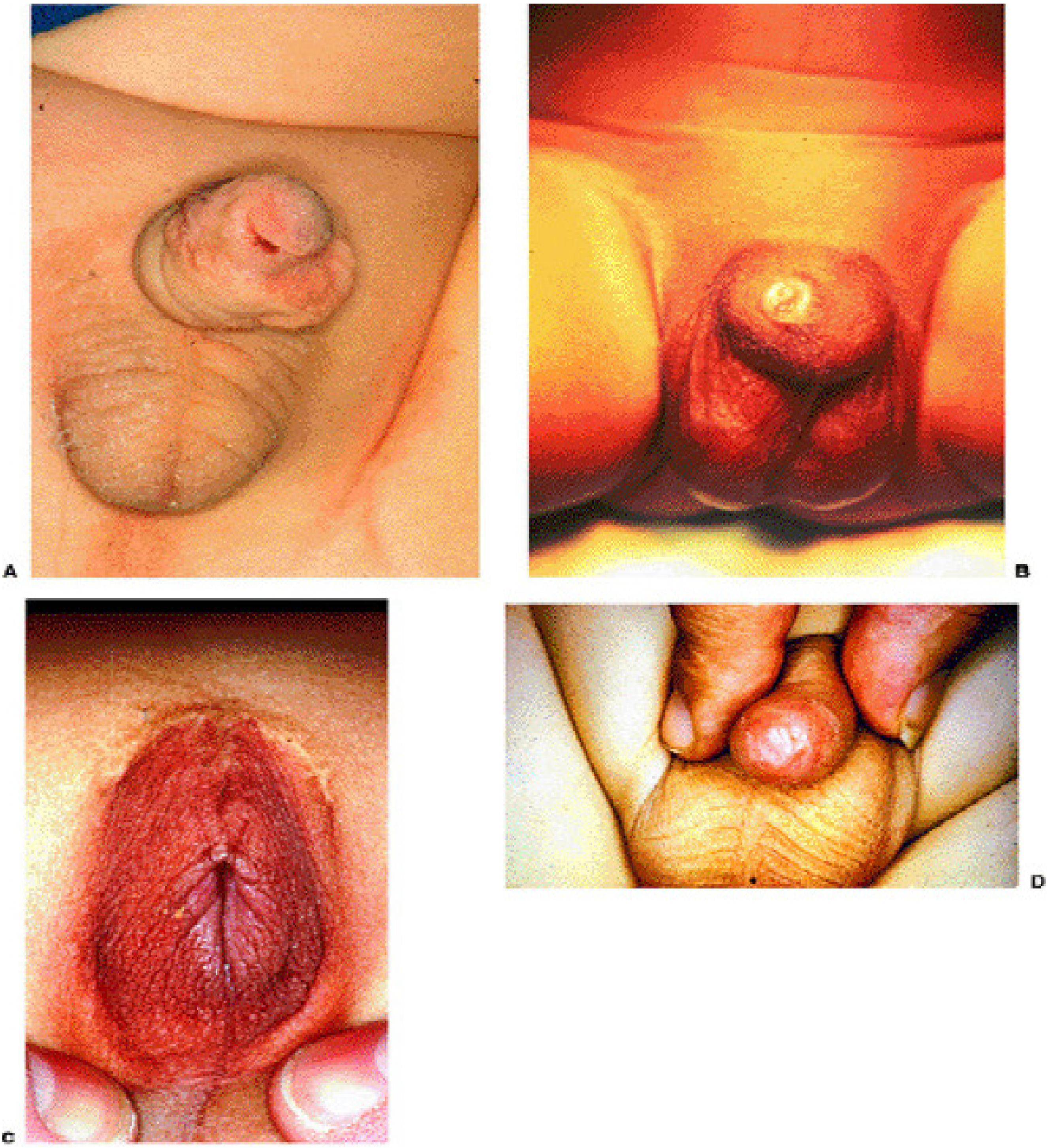

FIG. 44.6. Complication of circumcision. A: Glans injury 6 months after circumcision. B: Trapped penis following contraction of wound after circumcision. C: Penile amputation following cautery injury during circumcision. D: Cicatrix following circumcision.

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45-Drainage of Superficial Abscesses

An N. Massaro
Khodayar Rais-Bahrami

A. Definitions

A superficial abscess is

- A localized collection of pus that causes fluctuant soft tissue swelling and may have associated erythema and induration (Fig. 45.1) (1, 2,3 and 4)
- Usually caused by invasion of local bacterial flora (1) or direct inoculation, i.e., animal bites ((5)) or intravenous access/skin piercing (6,7 and 8)
- A result of bacterial organisms that cause necrosis, liquefaction, accumulation of leukocytes and debris, followed by loculation and walling off of pus (9)

B. Indications

- To establish free drainage of contents from a superficial abscess

  Surgical incision and drainage is the definitive treatment for soft tissue abscesses. Antibiotic therapy alone is ineffective in the setting of localized abscess and may even be unnecessary as an adjuvant to complete surgical drainage (1,2,10,11).

- To identify pathogens and direct antimicrobial therapy if needed (12, 13,14 and 15)
- To differentiate infectious from noninfectious lesions (13,16,17)

C. Contraindications

- Carefully identify and avoid:
  - Cephalohematoma
  - Hemangioma
  - Cystic hygroma
  - Encephalocele

- Avoid premature incision and drainage of abscesses that have not yet fully matured, i.e., in the initial stages of induration and inflammation prior to formation of pus (9). This may lead to:
  - A noncurative intervention
  - Possible extension of infectious process
  - Bacteremia

This may be avoided by the use of ultrasound with or without diagnostic needle aspiration (18,19).
D. Equipment
Sterile

- Gloves and gown
- Antiseptic swabs or cup containing antiseptic solution
- 1-mL syringe
- Nonbacteriostatic, isotonic saline without preservative
- 23-gauge needle
- 2 x 2-in gauze squares
- Scalpel with no. 11 blade
- Cotton-tipped culture swab
- Mosquito hemostat
- 2-in, fine-mesh, plain gauze

Nonsterile

- Ethyl chloride spray as topical anesthetic (For larger lesions, local anesthesia with lidocaine may be used.)
- Mask and cap
- Adhesive tape

E. Precautions

- Use appropriate isolation techniques to safeguard other infants.
- Obtain blood cultures after drainage.
- Do not suture abscess cavity following incision and drainage.
- DÃ©bride all tissue undergoing putrefaction and digestion thoroughly (4).
- Make skin incisions:
  - Conform with skin creases/natural folds to minimize scar formation
  - Large enough to allow for proper dÃ©bridement and drainage
  - Simple linearâ€“cruciate or elliptical skin incisions may result in more unsightly scar formation ((9)).
- For abscesses in cosmetic areas, areas under significant skin tension (i.e., extensor surfaces), or areas with extensive scar tissue (i.e., sites of prior drainage procedures), a stab incision or needle aspiration alone may be preferable. (This may require multiple decompressions and/or delayed complete incision and drainage if reaccumulation occurs.)
- Care should be taken in areas with abundant vascular and neural structures, such as the groin, posterior knee, antecubital fossa, and neck ((3)).
- If foreign body is suspected, a radiograph should be obtained ((9)).

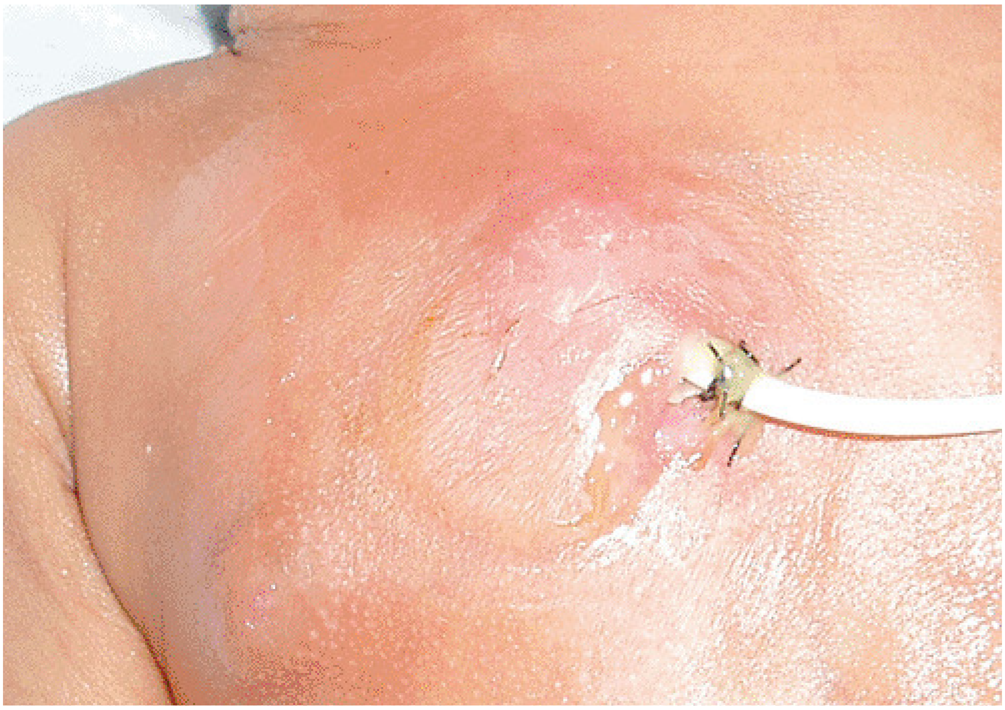

FIG. 45.1. Superficial abscess in the site of a Broviac central venous line insertion in the left anterior chest wall.

F. Technique (1,4,7,8)

- Spray roof of abscess with ethyl chloride until skin becomes white. (If local anesthesia is required, lidocaine can be injected subcutaneously with a 25-gauge needle into the dome of the abscess).
- Prepare as for major procedure if abscess is to be drained, or for minor procedure if needle aspiration alone is to be performed (see Chapter 4).
- Prepare local area with antiseptic (e.g., iodophor).
- Aspiration [may be performed in combination with incision and drainage for confirmation of presence of pus and collection of material for culture, or alone if abscess is in area where incision is not preferable (see E.6)].
    - Attach sterile needle to syringe.
    - Insert needle into pustule, abscess cavity, or advancing border of cellulitis.
    - Aspirate the material deep within the lesion.
    - If no material is aspirated, inject 0.1 to 0.2 mL of nonbacteriostatic saline and withdraw immediately.
    - Process aspirated material immediately: Gram stain and culture for anaerobic and aerobic organisms; Giemsa stain for suspected herpes. Perform other special stains as warranted.
- Incision and drainage
    - Insert scalpel blade and incise at point of maximum fluctuance. The size of the incision should be as small as possible yet allow for continued adequate drainage (i.e., length of the abscess cavity).
    - Obtain specimen for culture with cotton-tipped applicator, if not obtained by prior aspiration with syringe and needle.
    - Evacuate exudate from abscess with gentle pressure from finger or hemostat wrapped in gauze. Use caution when probing abscess with finger in cases of suspected retained foreign bodies or fragmentsâ€”for this reason, hemostat wrapped in gauze is the preferred method ((9)).

  - If necessary, insert mosquito hemostat into abscess cavity and spread blades to break septa and to release remaining collections of pus (Fig. 45.2A). Recognize that this may cause discomfort and should be done rapidly.
- Lavage area with sterile saline to remove residual pus (optional).
- If indicated, insert plain, ½-in gauze into abscess cavity to stop bleeding and/or to serve as a wick to promote drainage (Fig. 45.2B).
- Apply dry, sterile dressing.
- Remove half of gauze packing in 24 hours and remainder within 48 hours. (Some larger wounds may require multiple packing changes).
- Check abscess wound, and apply sterile warm soaks for 20 to 30 minutes, three times a day, until healing has commenced, as indicated by:
  - Cessation of drainage
  - Formation of granulation tissue
  - Resolution of local tissue inflammation

G. Complications

- Introduction of infection into sterile abscess or hematoma
- Local bleeding
- Injury to blood vessels, nerves, or tendons (deep to abscess cavity) (3)
- Incomplete drainage with recurrent abscess formation (2,4)
- Systemic infection (20,21)
- Scar formation at drainage site, requiring skin graft (22)
- Reduction of breast size following incomplete drainage of breast abscess (23)

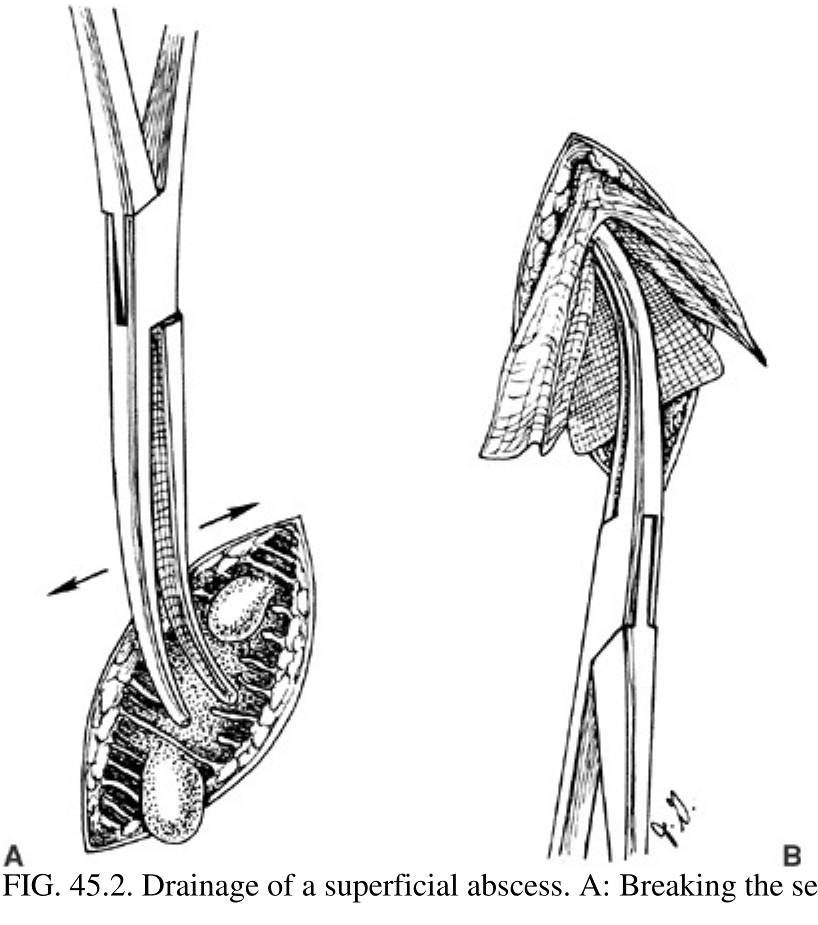

FIG. 45.2. Drainage of a superficial abscess. A: Breaking the septa with a clamp. B: Packing the wound.

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46-Phototherapy

Sepideh Nassabeh-Montazami

Phototherapy is the most common therapeutic intervention used for the treatment of hyperbilirubinemia (1). The process of phototherapy causes three reactions: photo-oxidation, configurational and structural isomerization of the bilirubin molecule, leading to polar, water-soluble photoproducts that can be excreted in bile and urine without the need for conjugation or further metabolism (2).
The aim of phototherapy is to reduce serum bilirubin levels in order to decrease the risk of acute bilirubin encephalopathy and the more chronic side effect of bilirubin toxicity, kernicterus (3).

A. Indications

- Clinically significant indirect hyperbilirubinemia. Indications to start phototherapy in babies with hyperbilirubinemia can vary depending on gestational age, birthweight, hours of life, presence of hemolysis, and other risk factors such as acidosis and sepsis (3,4).
- The total serum bilirubin (TSB) level must be considered when making the decision to commence treatment, as there is significant variability in laboratory measurement of direct bilirubin levels.
- The American Academy of Pediatrics has published clinical practice guidelines for phototherapy in newborn infants at 35 weeks' or more gestation (3) (Fig. 46.1).
- These guidelines do not apply to preterm infants less than 35 weeks' gestation. Preterm infants are at higher risk of developing hyperbilirubinemia compared to term infants. The decision to initiate phototherapy in this group of infants remains variable and highly individualized. The management of hyperbilirubinemia in extremely preterm and low-birthweight infants has been recently reviewed (4,5) (Table 46.1).
- Prophylactic phototherapy, often used for preterm infants with skin bruising, is ineffective until bilirubin appears in the skin.

B. Contraindications

- Congenital porphyria or a family history of porphyria is an absolute contraindication to the use of phototherapy. Severe purpuric bullous eruptions have been described in neonates with congenital erythropoietic porphyria treated with phototherapy (6).
- Concomitant use of drugs or agents that are photosensitizers is also an absolute contraindication (7).
- Concurrent therapy with metalloporphyrin heme oxygenase inhibitors has been reported to result in mild transient erythema (8).
- Although infants with cholestatic jaundice may develop the â€œbronze baby syndromeâ€□ when exposed to phototherapy (see Complications), the presence of direct hyperbilirubinemia is no longer considered to be a contraindication (3). However, because the products of phototherapy are excreted in the bile, the presence of cholestasis may decrease the effectiveness of phototherapy.

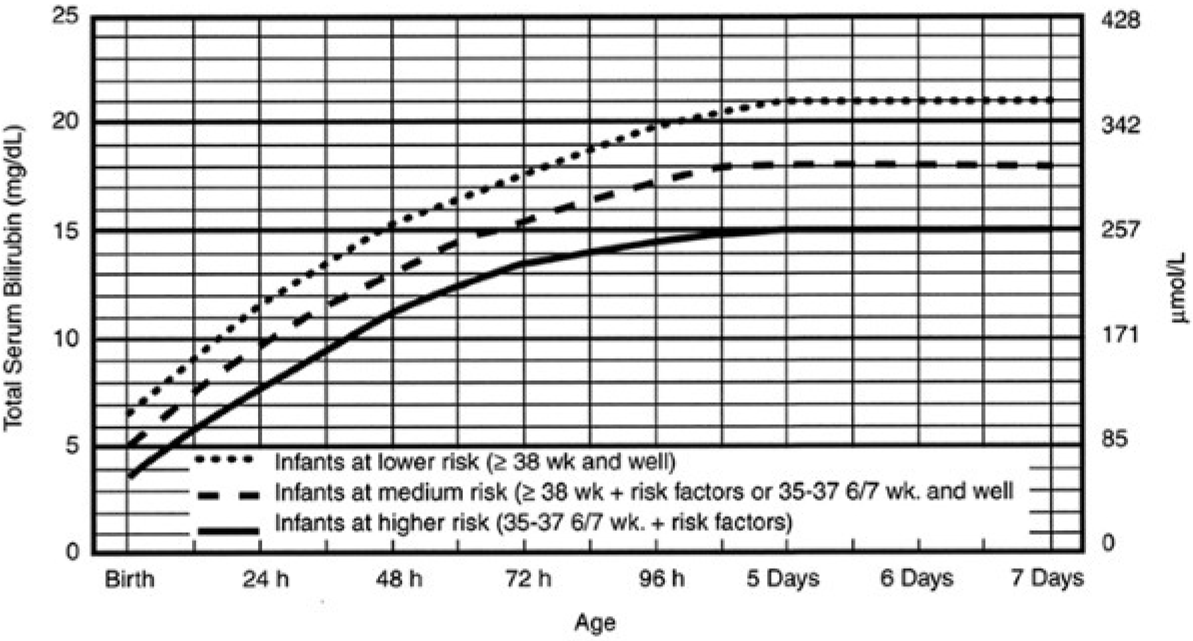
C. Equipment

In order to have an understanding of the equipment available for phototherapy, it is necessary to be familiar with the terminology involved.

- Spectral qualities of the delivered light (wavelength range and peak). Bilirubin absorbs visible light within the wavelength range of 400 to 500 nm, with peak absorption at 460 ± 10 nm considered to be the most effective (2).
- Irradiance (intensity of light), is expressed as watts per square centimeter (W/cm^2). This refers to the number of photons received per square centimeter of exposed body surface area.

- Spectral irradiance is irradiance that is quantitated within the effective wavelength range for efficacy and is expressed as ÂµW/cm^2/nm (9). This is measured by various commercially available radiometers. Specific radiometers are generally recommended for each phototherapy system, because measurements of irradiance may vary depending on the radiometer and the light source (3).

A variety of phototherapy equipment devices exist and may be free-standing, attached to a radiant warmer, wall-mounted, suspended from the ceiling, or fiber-optic systems. These in turn may contain various light sources to deliver the phototherapy, which may be categorized as:



- Use total bilirubin. Do not subtract direct reacting or conjugated bilirubin.
- Risk factors = isoimmune hemolytic disease, G6PD deficiency, asphyxia, significant lethargy, temperature instability, sepsis, acidosis, or albumin < 3.0g/dL (if measured)
- For well infants 35-37 6/7 wk can adjust TSB levels for intervention around the medium risk line. It is an option to intervene at lower TSB levels for infants closer to 35 wks and at higher TSB levels for those closer to 37 6/7 wk.
- It is an option to provide conventional phototherapy in hospital or at home at TSB levels 2-3 mg/dL (35-50mmol/L) below those shown but home phototherapy should not be used in any infant with risk factors.

FIG. 46.1. Guidelines for phototherapy in hospitalized infants of 35 or more weeks' gestation. (From American Academy of Pediatrics Subcommittee on Hyperbilirubinemia. Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. Pediatrics. 2004;114:297-316.)

- Fluorescent tubes
- Halogen bulbs
- Fiber-optic light combinations used in pads, blankets, or spotlights
- High-intensity light-emitting diodes

The clinician is therefore faced with a vast array of equipment to choose from and must be aware of advantages and disadvantages of each type.

TABLE 46.1 Guidelines for Use of Phototherapy and Exchange Transfusion in Preterm Infants Based on Gestational Age

Gestational Age (wk)	Total Bilirubin Level (mg/dL/µmol/L)		
		Exchange Transfusion	
	Phototherapy	Sick[a]	Well
36	14.6 (250)	17.5 (300)	20.5 (350)
32	8.8 (150)	14.6 (250)	17.5 (300)
28	5.8 (100)	11.7 (200)	14.6 (250)
24	4.7 (80)	8.8 (150)	11.7 (200)

[a] Rhesus disease, perinatal asphyxia, hypoxia, acidosis, hypercapnea.

Source: **Maisels MJ, Watchko JF**. Treatment of jaundice in low birthweight infants. *Arch Dis Child Fetal Neonatal Ed.* 2003;88:F459-F463.

- Fluorescent tubes
    - Special blue tubes, such as F20 T12/BB, provide more irradiance in the blue spectrum than other tubes and are the most effective fluorescent light source. (2) (Fig. 46.2). The special blue F20 T12/BB tubes provide much greater irradiance than regular blue tubes, labeled F20T12/B. The flickering glare of the blue light has been reported to cause giddiness, nausea, and temporary blurring of vision in nursing personnel (10). One way to overcome this has been to use cool white light in conjunction with the special blue, but this combination can decrease efficacy by as much as 50%, depending on the proportion of cool white light used

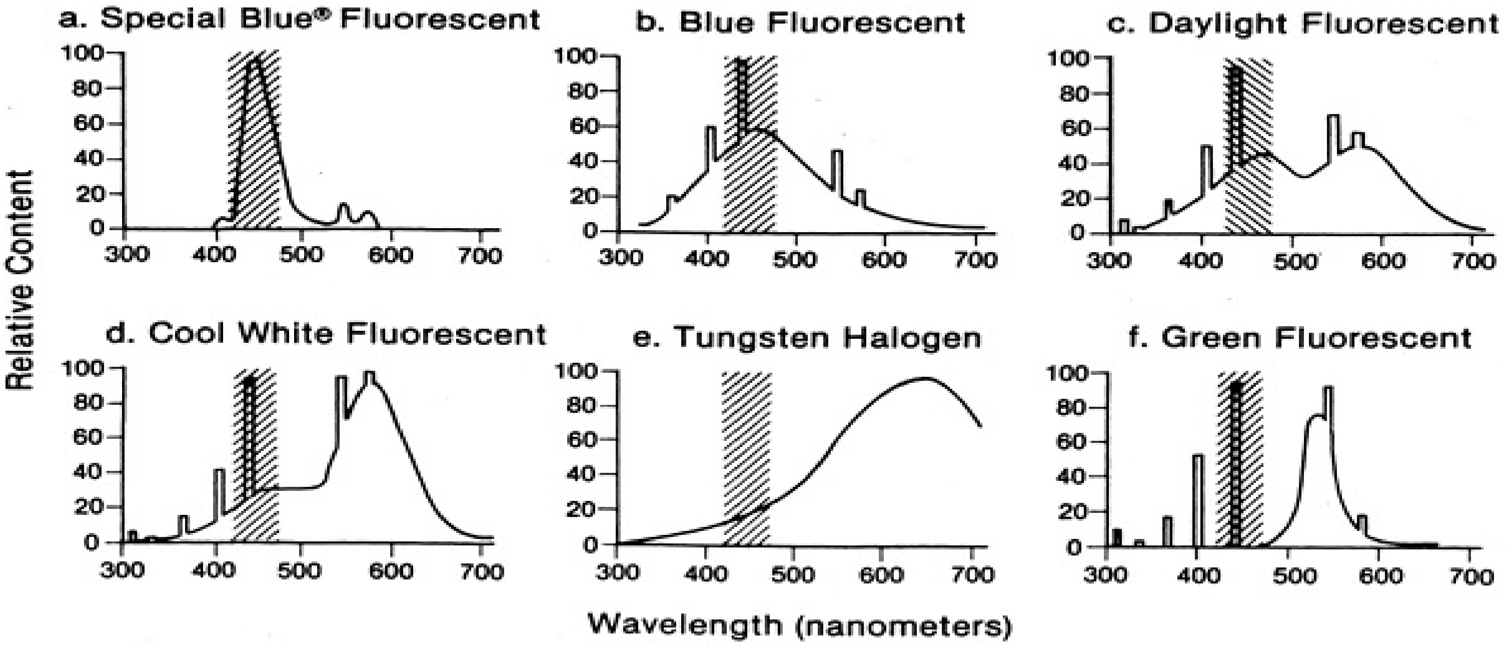


FIG. 46.2. Relative spectral content of phototherapy bulbs. Shaded area indicates wavelength effective for phototherapy. Absolute spectral irradiance (µW/cm^2/nm) depends not only on relative power across wavelength of bilirubin absorption but also on total wattage and distance from infant. Although all bulbs provide effective phototherapy for the same wattage, special blue and blue fluorescent bulbs provide the most amount of power in the bilirubin wavelength. (Based on data from Olympic Medical (d); from Warshaw JB, Gagliardi J, Patel A. A comparison of fluorescent and nonfluorescent light sources for phototherapy. Pediatrics. 1980;65:795-798(e); and from Farr PM, Diffey BL. The colour of light for neonatal phototherapy. Arch Dis Child. 1988;63:461-462(f).

  - Green/turquoise lamps penetrate the skin to a greater depth, but the advantage over blue light remains debated (12,13 and 14).
  - Cool white lamps may be inadequate in sufficiently decreasing total bilirubin levels unless the lights are positioned in close proximity to the infant (11). As mentioned above, this type of light has also been used together with special blue tubes.
  - Daylight lamps, like cool white lamps, have a wider wavelength spectrum and are less effective than blue light (11).
- Halogen lamps
  - Halogen spotlight systems utilize single or multiple metal halide lamps as the light source and can provide high irradiance over a small surface area (>20 ÂµW/cm^2/nm).
  - These units can generate considerable heat, with the potential of causing thermal skin injury; therefore, they must not be in close proximity to the patient.
  - The variable positioning with respect to the distance from the infant as well as heterogeneity of the irradiance can lead to unreliable dosing and unpredictable clinical responses. In addition, they are more expensive than fluorescent bulbs (2).
- Fiber-optic systems
  - UV-filtered light from a tungsten halogen bulb enters a fiber-optic cable and is emitted from the sides and end of fiber-optic fibers inside a plastic pad.
  - The pad emits insignificant levels of heat, so it can be placed in direct contact with the infant to deliver up to 35 µW/cm^2/nm of spectral irradiance, mainly in the blue green range (2,15).
  - The orientation of the fiber-optic fibers determines the uniformity of emission and is unique to each of the commercially available devices.
  - The main advantages of these systems are that, while receiving phototherapy, the infant can be held and/or nursed, thereby minimizing infant/parent separation. In addition, covering the infant's eyes is not necessary, preventing further parental anxiety.
  - The main disadvantage of the fiber-optic pads is that they cover a relatively small surface area, and therefore have less efficacy compared to overhead sources. They should not be used as the sole means of providing phototherapy in an infant with significant hyperbilirubinemia (2,3,10).
  - These devices are often used as an adjunct to conventional overhead application of phototherapy to provide â€œdouble phototherapy (circumferential phototherapy), which has greater efficacy because greater body surface area is exposed to the light (15).

    Two examples of fiber optic systems are

    - The Wallaby 3 Phototherapy System (Respironics, Norwell, MA, USA) delivers light at a wavelength of 425 to 475 nm with an average irradiance of 8 to 10 µW/cm^2/nm. Two sizes of fiber-optic light panels are available: a 4-in x 5-in neonatal panel and a 3-in x 14-in wrap-around panel, which may be wrapped around the infant.
    - The Homed BiliBlanket Phototherapy System (Ohmeda Medical, Laurel, MD, USA) delivers light at a wavelength of 400 to 550 nm; the intensity of light delivered can be controlled, permitting irradiance levels of 15, 25, and 35 µW/cm^2/nm. The fiber-optic panel consists of 2,400 fibers woven into a mat measuring 10 x 20 cm.
- Gallium nitride light-emitting diodes (LEDs)
  - These systems are semiconductor phototherapy devices capable of delivering high spectral irradiance levels of >200 ÂµW/cm^2/nm with very little generation of heat within a very narrow emission spectrum in the blue range (460 to 485 nm) (16,17).
  - LEDs have a longer lifetime (>20,000 hours) and have become cost-effective for use in phototherapy devices.
  - An example of an LED system is the neoBLUE System (Natus Medical, San Carlos, CA, USA). This device delivers blue light in the range of 450 to 470 nm with either a low-intensity (12 to 15 ÂµW/cm^2/nm) or a high-intensity (30 to 35 ÂµW/cm^2/nm) setting.

D. Technique (Conventional Phototherapy)

Intensive phototherapy is defined as the use of light in the 430- to 490-nm band delivered at 30 µW/cm^2/nm or higher to the greatest body surface area possible (3).

- Position phototherapy unit over infant to obtain desired irradiance (10 to 40 µW/cm^2/nm). Maximal amount of irradiance achieved by standard technique is generally 30 to 50 µW/cm^2/nm. The distance of the light from the infant has a significant effect on the intensity of phototherapy, and to achieve maximal intensity, the lights should be positioned as close as possible to the infant. Fluorescent tubes may be brought within approximately 10 cm of term infants without causing overheating, but halogen spot phototherapy lamps should not be positioned closer to the infant than recommended by the manufacturer, because of the risk of burns (3,18).
- If increased irradiance is required, add additional units or place a fiber-optic phototherapy pad under the infant (15). Additional surface area may be exposed to phototherapy by lining the sides of the bassinet with aluminum foil or a white cloth (19).
- Keep the photoradiometer calibrated and perform periodic checks of phototherapy units to make sure that adequate irradiance is being delivered (3).
- Maintain an intact Plexiglas shield over phototherapy light bulbs in order to block ultraviolet radiation and to protect the infant from accidental bulb breakage.
- Provide ventilation to the phototherapy unit to prevent overheating light bulbs.
- Maintain cleanliness and electrical safety.

E. Technique (Fiber-Optic Phototherapy)

Fiber-optic phototherapy can be used as the sole source of phototherapy or as an adjunct to conventional treatment.

- Insert panel into disposable cover so that it is flat and directed toward infant.
- Place covered panel around infant's back or chest and secure in position. Phototherapy blanket/pad must be positioned directly next to the infant's skin to be effective.

  Avoid constriction and skin irritation under the infant's arms if the panel is wrapped around the infant.

- Discard disposable covers after each treatment and when soiled.
- Use eye patches if there is any direct exposure to lights in panel or if used with conventional phototherapy for double-sided effect.
- Ensure stability and adequate ventilation of illuminator unit by placing on a secure surface.
- Connect fiber-optic panel to illuminator.
- Keep fiber-optic panel and illuminator clean and dry.
- Allow lamp to cool for 10 to 20 minutes before moving illuminator. Do not place sharp or heavy objects on panel or cable.

Care of the Infant Receiving Phototherapy

- Monitor temperature, particularly of infants in an incubator, who may develop hyperthermia.
- Monitor intake, output, and weight. Fluid supplementation may be necessary secondary to increased insensible losses and frequent stooling. Encourage breast feeding. Healthy term breast-fed infants may be supplemented with milk-based formula if maternal milk supply is inadequate. Intravenous fluids are rarely required. Milk feeding inhibits the enterohepatic circulation of bilirubin (3).
- The use of eye protection in the form of eye patches is necessary for infants receiving overhead phototherapy. Masks adhering directly to Velcro tabs on the temples are preferable to circumferential headbands.

- Maximize skin exposure to phototherapy source by using the smallest possible diapers as well as keeping blanket rolls from blocking light.
- Avoid fully occlusive dressings, bandages, topical skin ointments, and plastic in direct contact with the infant's skin, to prevent burns.
- Remove plastic heat shields and plastic wrap that decrease irradiance delivered to the skin (20).
- If in use, shield the oxygen saturation monitor probe from the phototherapy light.
- Encourage parents to continue feeding, caring for, and visiting their infant.

F. Home Phototherapy

Home phototherapy decreases costs of hospitalization and eliminates separation of mother and infant. It is safe and effective for selected infants. Home phototherapy should be used only in infants whose bilirubin levels are in the â€œoptional phototherapy range (Fig. 46.1).

- Make arrangements to measure infant's serum bilirubin every 12 to 24 hours, depending on the previous concentration and rate of rise. The infant should be examined daily by a visiting nurse or at an office.
- The supervising physician should be in contact with the family daily during the period of treatment.
- The infant should be rehospitalized if he or she shows signs of illness or if the serum bilirubin concentration exceeds 18 mg/dL.

Efficacy of Phototherapy

The therapeutic efficacy of phototherapy depends on several factors.

- Exposed body surface area: The greater the area exposed, the greater the rate of bilirubin decline
- Distance of the infant from the light source
- Skin thickness and pigmentation
- Total bilirubin at clinical presentation
- Duration of exposure to phototherapy

G. Discontinuation of Phototherapy and Follow-Up

- There is no standard for discontinuing phototherapy. The total serum bilirubin (TSB) level that determines the discontinuation of phototherapy depends on the age at which treatment was initiated and the etiology of hyperbilirubinemia (3,21).
- For infants who are readmitted to hospital (usually for TSB levels of 18 mg/dL or higher), phototherapy may be discontinued when the serum bilirubin level falls below 13 to 14 mg/dL.
- For infants who are readmitted with hyperbilirubinemia and then discharged, significant rebound is uncommon, but may still occur. In cases of prematurity, positive direct antiglobulin (Coombs) test, and for babies treated less than 72 hours, the likelihood of rebound is much higher, and these risk factors should be taken into account when planning postphototherapy follow-up (22,23 and 24). Generally, a follow-up bilirubin measurement within 24 hours after discharge is recommended (3).

H. Complications of Phototherapy

Phototherapy has been used in millions of infants for more than 30 years, and reports of significant toxicity are exceptionally rare(3).

Complications include the following.

- Bronze baby syndrome occurs in some infants with cholestatic jaundice who are exposed to phototherapy, as a result of accumulation in the skin and serum of porphyrins. The bronzing disappears in most infants within 2 months (25). Rare complications of purpuric eruptions due to transient porphyrinemia have been described in infants with severe cholestasis who receive phototherapy (26).
- Diarrhea or loose stools (27)
- Dehydration secondary to insensible water loss
- Skin changes ranging from minor erythema, increased pigmentation, and skin burns to rare and more severe blistering and photosensitivity in infants with porphyria and hemolytic disease
- Potential retinal damage from light exposure if eye patches are not used effectively (28).
- Separation of mother and infant and interference with bonding.

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47-Intraosseous Infusions

Mary E. Revenis

A. Indications

- Emergency intravenous access when other venous access is not readily available; to restore intravascular volume so that peripheral venous access becomes possible. See Table 47.1 for categories of fluid that have been infused (1,2,3 and 4).

B. Contraindications (3,5,6)

- Bone without cortical integrity (fracture, previous penetration): Extravasation of infusate
- Sternal site: Potential damage to heart and lungs (7)
- Overlying soft tissue infection
- Osteogenesis imperfecta
- Obliterative diseases of marrow such as osteopetrosis

C. Equipment
Sterile

- Surgical gloves
- Cup with antiseptic solution
- Gauze squares
- Aperture drape
- 1% lidocaine in 1-mL syringe with 25-gauge needle
- Needle, in order of preference (1,2,3,8)

  - Bone marrow or intraosseous needle (18-gauge) (stylet and adjustable depth indicator preferred)
  - Short spinal needle with stylet (18- or 20-gauge)
  - Short hypodermic needle (18- or 20-gauge)
  - Butterfly needle (16- to 19-gauge)
- 5-mL syringe on a three-way stopcock and IV extension set with clamp
- Syringes with saline flush solution
- Intravenous infusion set and intravenous fluid

Nonsterile

- Small sand bag or rolled towel to aid in stabilizing limb
- Tape
- Armboard
- Disposable plastic cup

Optional
Intraosseous needle placement device (intended for use at the proximal tibial location). Devices approved for newborns are the spring-activated B.I.G. Bone Injection Gun (Waismed, Houston, TX, USA) and the battery operated driver EZ-IO Pediatric (Vidacare, San Antonio, TX, USA). Information on use of these devices in premature infants is scarce and as yet unpublished. It is not known if the incidence of success or complications using these devices differs compared to manual insertion of the intraosseous needle.

D. Precautions

- Limit use to emergency vascular access, when peripheral or central venous access is not feasible.
- Avoid inserting needle through infected skin or subcutaneous tissue.
- Stabilize limb with counterpressure, with sand bag or towel roll directly opposite proposed site of penetration, to avoid bone fracture.
- If hand is used to stabilize limb, do not position hand behind puncture site, to avoid inadvertent puncture of hand by the intraosseous needle if it goes through the limb. This is true regardless of whether a sand bag or towel is used. It is at times helpful to use the hand to help stabilize the limb, but it must be done without injury to the practioner.
- Limit needle size to decrease chance of fracture of bone.
- Administer drugs in the usual doses for intravenous administration; however, when possible, dilute hypertonic or strongly alkaline solutions prior to infusion, to reduce risk of bone marrow damage (2).
- Discontinue intraosseous infusion as soon as alternative venous access is established, to reduce risk of osteomyelitis.

E. Technique

Proximal tibia (1,2,3,9,10) (Fig. 47.1)

- Position patient supine.
- Place sand bag or towel roll behind knee to provide countersupport behind puncture site.
- Clean proximal tibia with antiseptic solution.
- Put on sterile gloves.

TABLE 47.1 Types of Intraosseous Infusates Reported in the Literature (4,15,17,21)

1. Fluids
    a. Normal saline
    b. Crystalloids
    c. Glucose (dilute if possible when using D50) (15,22)
    d. Ringer's lactate (17)
2. Blood and blood products
3. Medications
    a. Anesthetic agents
    b. Antibiotics
    c. Atropine (17)
    d. Calcium gluconate
    e. Dexamethasone (17)
    f. Diazepam (17)
    g. Diazoxide (17); phenytoin (23)
    h. Dobutamine (21)
    i. Dopamine (21,22,24)
    j. Ephedrine (25)
    k. Epinephrine (25)
    l. Heparin (17)
    m. Insulin
    n. Isoproterenol (24)
    o. Lidocaine
    p. Morphine
    q. Sodium bicarbonate (dilute if possible) (15,26)
4. Contrast material (27)

- Apply aperture drape.
- If appropriate, inject lidocaine into skin, soft tissue, and periosteum (11).
- Determine penetration depth on needle: Rarely more than 1 cm in infants.
    - For needle or bone needle injection device with adjustable depth indicator, adjust sheath to allow desired penetration.
    - For needle without an adjustable depth indicator, hold the needle in the dominant hand with blunt end supported by the palm and the index finger approximately 1 cm from the bevel of the needle, to avoid pushing it past this mark.
- Palpate tibial tuberosity with index finger.

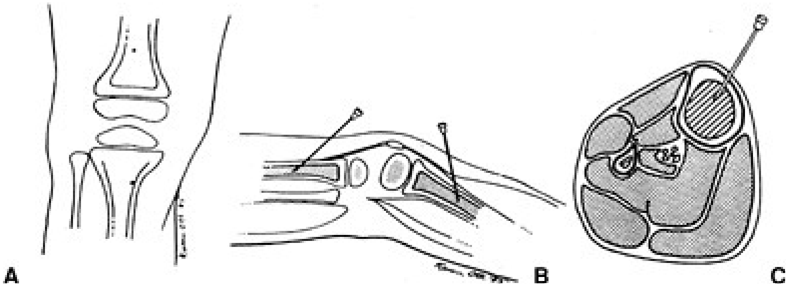

FIG. 47.1. A: Anterior view. B: Sagittal section. C: Cross section through tibia.

- Hold the thigh and knee above and lateral to the insertion site with the palm of the nondominant hand. Wrap fingers and thumb around the knee to stabilize the proximal tibia.
- Insert needle on the flat, anteromedial surface of the tibia, 1 to 2 cm below the tibial tuberosity.
- Direct needle at an angle of 10 to 15 degrees toward the foot, to avoid the growth plate.

- Advance needle.
  - For manual insertion, advance needle using firm pressure with a twisting motion until there is a sudden, slight decrease in resistance, indicating puncture of the cortex.
  - If an automatic spring-activated intraosseous needle injection device is used, hold the cylinder against the puncture site at a 90-degree angle with one hand. Release the safety latch on the cylinder with the other hand. Depress the cylinder, as with a syringe, without the use of force.
  - If a battery-operated driver with attached needle is utilized, hold the driver in the dominant hand. Position the needle against the puncture site at a 90-degree angle. Depress the trigger to activate the driver. Do not force the driver, but apply firm, steady pressure, allowing the driver to insert the needle. Stop when there is a sudden decrease in resistance.
- Do not advance the needle beyond cortical puncture.
- Remove the stylet.
- Confirm the position of the needle in the marrow cavity.
  - Needle should stand without support.
  - Securely attach a 5-mL syringe and attempt to aspirate blood or marrow. Aspiration is not always successful when using an 18- or 20-gauge needle.
  - If bone marrow is aspirated, it can be analyzed for blood chemistry values, partial pressure of arterial carbon dioxide, pH, hemoglobin level (12,13), type and cross-match, or cultured (13).
  - Attach syringe of saline flush solution and infuse 2 to 3 mL slowly, while palpating the tissue adjacent to the insertion site to detect extravasation. There should be only mild resistance to fluid infusion.
- If marrow cannot be aspirated and significant resistance to fluid infusion is met:
  - The hollow bore needle may be obstructed by small bone plugs.
    - Reintroduce the stylet, or
    - Introduce a smaller-gauge needle through the original needle.
    - Attach syringe of saline flush and flush 2 to 3 mL of fluid.
  - The bevel of the needle may not have penetrated the cortex.
    - Redetermine estimated depth needed.
    - Advance.
    - Flush with saline.
  - The bevel of the needle may be lodged against the opposite cortex.
    - Withdraw needle slightly.
    - Flush with saline.
- Observe the site for extravasation of fluid, indicating that:
  - The placement is too superficial, or
  - The bone has been penetrated completely.
  - If extravasation occurs, withdraw needle and select a different bone.
- When needle position is confirmed:
  - Attach syringe and infuse medications or fluid directly into the needle or via an IV extension set with clamp. Clear medications with saline flush.
  - For continuous infusion, attach a standard intravenous infusion set with an infusion pump to the intraosseous needle and administer at the same rate as for IV infusion (2).
- Secure intraosseous needle and maintain a clean infusion site while the needle is in place.
  - Tape the flanges of the needle to the skin to prevent dislodgement. If a needle safety latch is provided, attach the latch and then apply tape.
  - If desired, cover the exposed end of the needle with a disposable cup, taping the cover down. Cutting off the bottom of the cup will aid in visualization of the site for monitoring.
- Secure intravenous tubing with tape to the leg.
- Secure the leg to the armboard.
- Obtain radiograph to confirm position of needle and to rule out fracture.

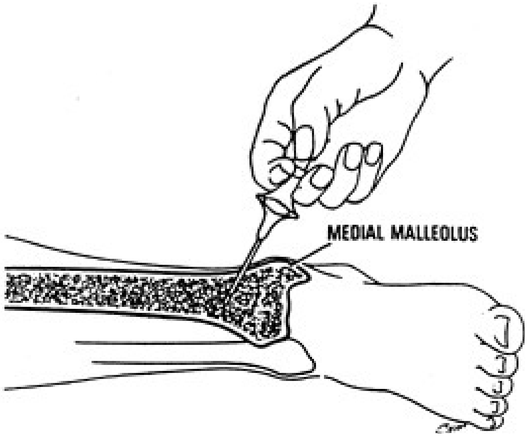

FIG. 47.2. Intraosseous infusion into the distal tibia. [Reproduced with permission from Spivey WH. Intraosseous infusions. J Pediatr. 1987;111(5):639.]

- Discontinue intraosseous infusion as soon as alternative intravenous access is achieved.

  In an infant with hypotension/hypovolemia, infusion via the interosseous route can restore peripheral perfusion to a point at which venous access is possible in well under 30 minutes.

  - Remove needle.
  - Apply a sterile dressing over the puncture site.
  - Apply pressure to the dressing for 5 minutes.

Distal tibia (2,8) (Fig. 47.2)

- Position patient supine.
- Prepare site and needle as for proximal tibia.
- Insert needle in the medial surface of the distal tibia just proximal to the medial malleolus.
- Direct needle cephalad away from the joint space.
- Proceed as for proximal tibia.

Distal femur (1,3,9) (Fig. 47.1)

- Position patient supine.
- Place sand bag or towel roll behind knee.
- Prepare site and needle as for proximal tibia.
- Insert needle 1 to 3 cm above the external condyles in the anterior midline.
- Direct needle cephalad at an angle of 10 to 15 degrees.
- Proceed as for proximal tibia.

F. Complications (1,4,14,15)

- Fracture of bone (16)
- Complete penetration of bone (17)
- Osteomyelitis (14,15)
- Periostitis (15)
- Subcutaneous abscess
- Cellulitis
- Sepsis
- Extravasation of fluid from the puncture site

- Subperiosteal or subcutaneous infiltration or hematoma
- Compartment syndrome (18)
- Subcutaneous sloughing
- Death (reported only with sternal bone site) (7)
- Theoretical (as yet unreported) (19,20)
    - Embolization of bone fragments or fat
    - Damage to bone marrow
    - Damage to growth plate

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48-Tapping Ventricular Reservoirs

Secelela Malecela

The subcutaneous ventricular access device (Fig. 48.1) is used as a temporary measure to drain cerebrospinal fluid (CSF) in preterm infants with posthemorrhagic hydrocephalus while awaiting permanent ventriculoperitoneal (VP) shunt placement (1,2,3,4,5,6,7).

A ventricular reservoir is often inserted in preterm infants who are too small or too unstable to have a VP shunt. A ventricular reservoir also allows for drainage and clearing of the initial CSF, which is bloody and has a high protein content, thus decreasing the risk of shunt blockage (5,6 and 7).

The reservoir is usually tapped immediately following placement by the neurosurgeon to ensure proper placement and to drain excess CSF (5). Subsequent taps are performed in the neonatal intensive care unit (NICU), aiming to remove enough CSF to prevent further ventriculomegaly and maintain normal head growth (5,6,8).

A. Indications

- Rapidly increasing head circumference, more than 1 cm/week
- Clinical signs of raised intracranial pressure evidenced by a full or tense anterior fontanelle, separation of the sutures, apnea and bradycardia, poor feeding and vomiting
- Ultrasound or radiologic evidence of progressive ventriculomegaly

B. Contraindications

- Low circulating blood volume
- Cellulitis or abrasion over the reservoir site
- Sunken fontanelle or overlapping sutures
- Severe coagulopathy

C. Equipment

- Mask, cap, sterile gloves
- Standard infant lumbar puncture set
- Povidineâ€“iodine surgical scrub and prep solution
- Aperture drape
- Scalp-vein needle (25- or 27-gauge)
- 20-mL syringe

D. Precautions

- Use strict aseptic technique.
- Maintain continuous cardiorespiratory monitoring during the procedure.
- Do not use local anesthetic.
- Do not place intravenous lines on the same side of the scalp.
- Do not shave the operative area.
- Always use a fresh site for insertion of the needle with every tap.
- Avoid puncturing the bottom of the reservoir.

E. Technique

- Infant should be restrained and comfortable, with the head in neutral position.
- Clip any long hair that interferes with the surgical area but do not shave the operative area.
- Clean skin over the reservoir and a radius of 5 cm of the surrounding skin using surgical scrub. Use light but firm contact. Clean for 5 to 10 min.
- Dry with blotting pads.
- Don mask and cap.
- Scrub hands and put on sterile gloves.
- Paint area with povidineâ€“iodine solution and allow area to dry.
- Drape area while maintaining patient visibility.
- Insert scalp-vein needle at an angle of 30 to 45 degrees through the skin into the reservoir bladder (Fig. 48.2).
- Aspirate fluid at a rate of 1 to 2 mL/min. Remove no more than 10 to 15 mL/kg. Some authors advocate letting the CSF drain spontaneously, rather than aspirating, in order to reduce fresh bleeding into the ventricles (9).
- Remove needle and hold firm pressure for 2 minutes, until CSF leakage from the skin stops.
- Clean area with sterile saline to remove the povidineâ€“iodine.
- Remove the restraints.
- Send CSF sample for culture, cell count, glucose, and protein. This should be done every 3 days. If fluid is dark and bloody, it is reasonable to send only a culture sample.

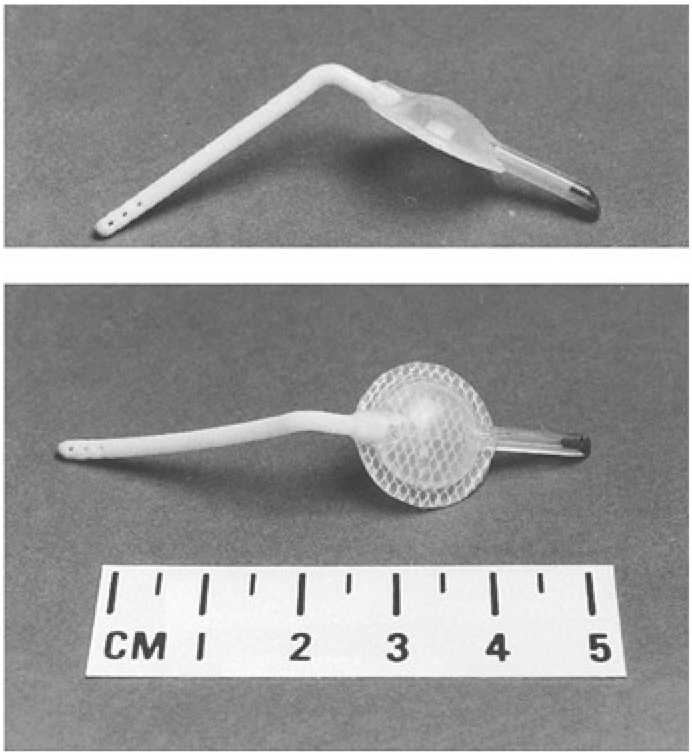

FIG. 48.1. McComb reservoir. Ventricular access device: side (top) and front views (bottom).

F. A Successful Tap

- At the end of the procedure the anterior fontanelle should be soft and flat (not sunken) and the cranial bones should be approximated well at the sutures.
- If sufficient volume is removed, the fontanelle may be full 24 hours later, but the sutures should not split apart.
- If the fontanelle remains slack, the interval for tapping may be lengthened to every other day and/or the amount of CSF removed at each tap reduced.

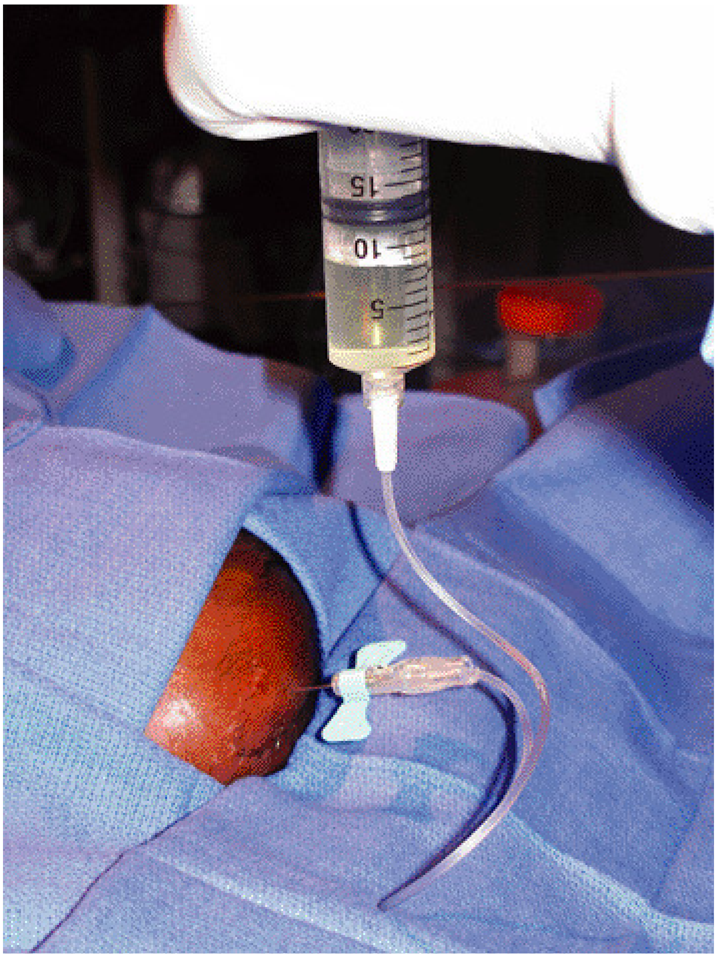

FIG. 48.2. Tapping of the reservoir.

TABLE 48.1 Complications of Ventricular Reservoir Drainage

Problem (Incidence)	**What To Do**
Hyponatremia (20%â€“60%)	Monitor serum electrolytes every other day and supplement sodium intake.
Hypoproteinemia (15%)	Ensure adequate protein intake. Monitor serum albumin weekly.
Infection (0%â€“8%)	A combination of intravenous and intrareservoir antibiotics may rarely be successful. Removal of the reservoir is usually necessary.
Subgaleal CSF collection (0%â€“9%)	Percutaneous aspiration of fluid using a different needle at the same time as the reservoir is tapped. Tap larger volume of CSF from the reservoir or increase frequency of taps to reduce pressure.
CSF leaks through incision (0%â€“3%)	Increase frequency of reservoir taps.
Ventricular access device occlusion (0%â€“10%)	Replace reservoir.
Trapped contralateral ventricle (6%)	Place second reservoir.
Fresh bleeding into the ventricle (0%â€“40%)	Prevent by using 25- or 27-gauge needle, aspirate slowly or let CSF drain spontaneously rather than aspirating.
Bradycardia, pallor, hypotension (rare)	Stop aspiration. Infuse 10â€“15 mL/kg of normal saline IV rapidly. Remove a smaller volume at a slower rate at next tap.
Skin breakdown over reservoir (rare)	Avoid abraded skin when tapping the reservoir. Avoid excoriating skin while prepping site.

G. Follow-Up

- Assess clinical response to taps, daily head circumference, and weekly cranial ultrasonography.
- Interval between taps may range from twice a day to once every 2 to 3 days.
- Taps should be continued until the infant weighs 2 kg and is a suitable candidate for shunt placement or until the hydrocephalus resolves.

H. Complications

See Table 48.1 (1,2,3,4,5,6,7,8,9,10).

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49-Laser for Retinopathy of Prematurity

William F. Deegan
Marijean Miller

A. Classification of Retinopathy of Prematurity (ROP) (1)

- Location (Fig. 49.1)
    - Zone I: Circle whose center is the optic disc and whose radius is twice the distance from the optic disc to the center of the macula
    - Zone II: Circle whose radius extends from the optic disc to the nasal ora serrata and is peripheral to Zone I
    - Zone III: Temporal crescent of retina anterior to Zone II

- Extent of disease

  The retina is divided into 12 equal segments, or clock hours. The extent of retinopathy specifies the number of clock hours involved.

- Staging the disease (1,2) (Figs. 49.2 and 49.3)
  - Stage 1 demarcation line: A flat white line in the plane of the retina, separating avascular retina anteriorly from vascularized retina posteriorly
  - Stage 2 ridge: Elevated fibrovascular tissue extending out of the plane of the retina and separating the vascularized and avascular retina
  - Stage 3 neovascularization of the ridge: Neovascular tissue extending from the ridge into the vitreous. This tissue may cause the ridge to appear ragged or â€œfuzzyâ€□ (Fig. 49.2).
  - Stage 4 retinal detachment: A separation of the retina from the underlying choroid. Usually, traction by the vitreous, through the presence of neovascular tissue, pulls the retina away from its underlying attachments. The intervening (subretinal) space fills with a proteinaceous fluid. A stage 4A detachment spares the macula; a stage 4B involves the macula. Retinal detachments in ROP require more extensive intervention, i.e., incisional surgery (scleral buckling and/or vitrectomy) (3).
  - Stage 5 total retinal detachment: Retinal tissue becomes inextricably bound to reactive vitreous and is pulled by the vitreous into the retrolental space (hence the older term, retrolental fibroplasia).
  - Plus disease: Dilation and tortuosity of retinal vessels due to high-flow shunting in advanced ROP. This is seen best in the posterior pole.
  - Threshold ROP: Traditionally (CRYO-ROP) defined as 5 contiguous or 8 total clock hours of stage 3 with Plus in Zone(s) I and/or II. Any stage 3 or any Plus in Zone I ROP should be treated. The Early Treatment for Retinopathy of Prematurity (ET-ROP)

    Study (4) devised a risk score that further stratifies â€œthresholdâ€□ and suggests earlier, â€œprethresholdâ€□ treatment in some infants. These include babies with stage 2â€“3 with Plus disease in Zone II.

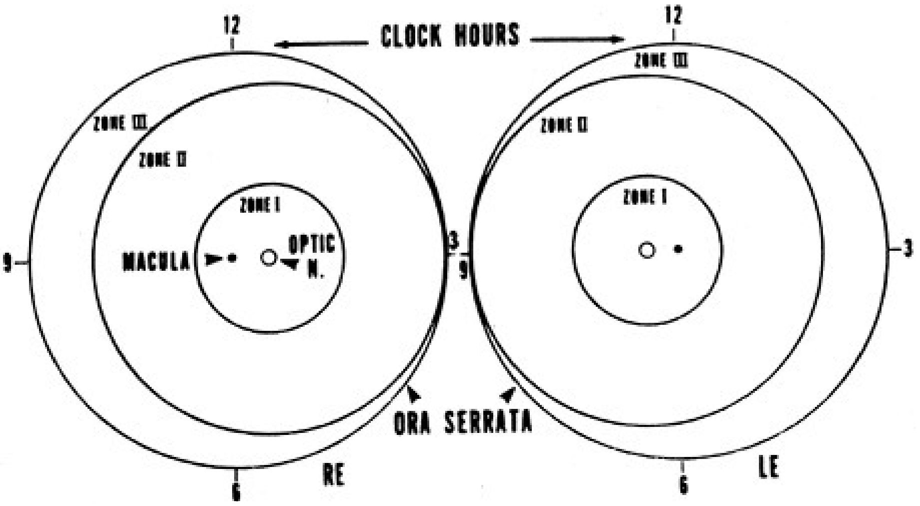

FIG. 49.1. Scheme of retina of right eye (RE) and left eye (LE), showing zone borders and clock hours employed to describe location and extent of retinopathy of prematurity. (From Committee for Classification of Retinopathy of Prematurity. An international classification of retinopathy of prematurity. Arch Ophthalmol. 1984;102:1130, with permission.)

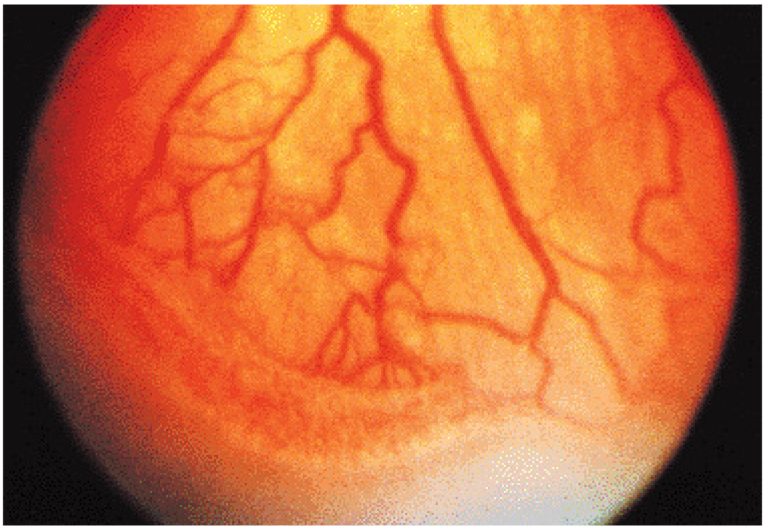

FIG. 49.2. Dilated, tortuous vessels end in vascular shunts at a thickened ridge of fibrovascular tissue. Avascular retina lies anterior to the ridge.

- Additional features: Iris vascular engorgement (Fig. 49.3) and pupillary rigidity (manifested by poor dilation after mydriatic instillation) (5) are harbingers of active, advanced ROP; corneal and lenticular opacity can be seen in the eyes of any premature infant regardless of the presence of ROP.

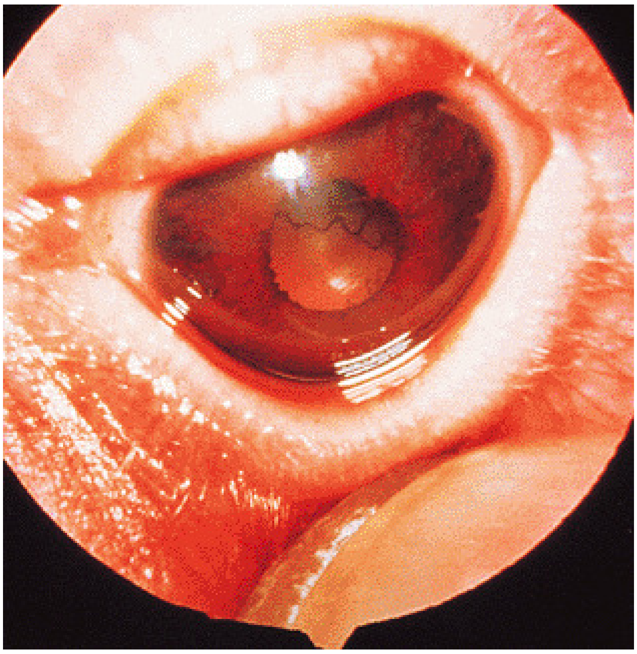

FIG. 49.3. Dilation and tortuosity of iris vessels may be seen in severe threshold retinopathy of prematurity.

B. Screening for Retinopathy of Prematurity (2)

Indirect ophthalmoscopy with scleral depression is the only method that can accurately screen and monitor babies with ROP. All babies born at <1,500 g and/or 32 weeks' or less gestational age should be screened, and infants weighing >1,500 g or more than 32 weeks' gestation should be considered for screening if they have had a particularly unstable clinical course, e.g., those requiring cardiopulmonary support. The exams are done at the bedside with the assistance of the baby's nurse.

The timing of the first exam varies with gestational age. The initial examination for infants born between 22 and 27 weeks' gestational age is at 31 weeks postconceptional age (gestational age at birth plus chronological age). Infants born later than 27 weeks' should be screened initially 4 weeks after birth. Follow-up exams depend on the retinal findings as classified by the International Classification of ROP. Table 49.1 has been adapted from the joint policy statement of the American Academies of Pediatrics and Ophthalmology, and the American Association for Pediatric Ophthalmology and Strabismus (2).
Babies whose clinical condition deteriorates should be followed closely, i.e., weekly, as late reactivation and worsening are possible.

C. Indications for Laser (2,4,6)

- The guidelines for consideration of ablative treatment for ROP have been revised recently, according to the Early Treatment for Retinopathy of Prematurity Study.
    - Zone I: Any stage of ROP with Plus disease or stage 3 without Plus disease
    - Zone II: Stage 2 or 3 ROP with Plus disease
- Babies who meet the traditional definition of threshold in Zones II and III according to the Multicenter Trial of Cryotherapy for Retinopathy of Prematurity (CRYO-ROP): stage 3 ROP in Zone I or II in 5 or more continuous clock hours or 8 cumulative clock hours, with Plus disease
- Treatment is recommended within 72 hours of detection of a stage of ROP requiring ablative therapy, when possible, in order to minimize the risk of retinal detachment.

TABLE 49.1 Follow-up Examination Schedule (2)

Findings	**Follow-up**
Stage 1-2 in Zone 1	1 wk or less
Stage 3 in Zone II	
Immature retina (no ROP) in Zone I	1-2 wk
Stage 2 in Zone II	
Regressing ROP in Zone I	
Stage 1 in Zone II	2 wk
Regressing ROP in Zone I	
Immature retina (no ROP) in Zone II	2-3 wk
Regressing or Stage 1-2 in Zone III	

D. Contraindications

- Stage 4 to 5 ROP, in which case laser may be done (intraoperatively) in conjunction with incisional surgery (scleral buckle, vitrectomy, or both)
- Vitreous hemorrhage sufficient to obscure a view of the retina
- Instability of medical condition sufficient to make the stress of sedation and laser inadvisable
- Lethal medical illness

E. Laser Treatment

Personnel

- Ophthalmologist
    - Determines the need for treatment
    - Administers topical anesthetic
    - Ensures that all personnel present at the treatment are wearing laser safety goggles
    - Performs the laser
    - Watches for and treats ocular complications that may arise during and after the procedure
    - Follows the baby postoperatively until ROP is resolved
- Neonatology fellow, attending neonatologist, or pediatric anesthesiologist

  - Administers systemic sedative agents (midazolam, fentanyl, ketamine, or a combination)
  - Monitors patient for and treats any systemic complications that develop during or after treatment
  - Provides information to the ophthalmologist regarding the patient's overall condition throughout the procedure
- Assistant to the ophthalmologist
  - Helps with laser and instruments
  - Records the treatment parameters used during treatment
- Neonatal nurse
  - Instills dilating drops several times in the hour preceding treatment
  - Immobilizes the patient during treatment
  - Monitors the patient's airway

Equipment

- Cardiorespiratory, blood pressure, and transcutaneous oxygen monitors
- Appropriate respiratory support (ventilator, laryngoscope and endotracheal tubes, face mask, self-inflating resuscitation bag, suction, and oxygen source)
- Emergency medications (atropine, epinephrine, bicarbonate, calcium, phenobarbital)

  Note: Precalculation of weight-appropriate doses is helpful.

- Topical ocular anesthetic, e.g., tetracaine, proparacaine
- Cycloplegic/mydriatic eye drops: Cyclomydril (Alcon Laboratories, Fort Worth, TX, USA) (cyclopentolate hydrochloride 0.2% and phenylephrine hydrochloride 1%) or 0.5% cyclopentolate and 1% or 2.5% phenylephrine
- Calcium alginate-tipped nasopharyngeal applicators or Flynn depressor (Fig. 49.4), for scleral depression
- Balanced salt solution for rewetting cornea during procedure
- Neonatal eyelid speculum (Fig. 49.4)
- 28- and 20-diopter lenses
- Portable argon or diode laser (7,8) with indirect (headlamp) delivery system
- Appropriate laser safety goggles

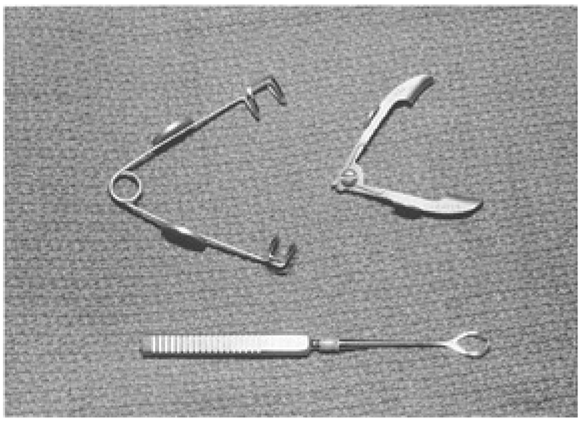

FIG. 49.4. Lid speculae and Flynn depressor.

F. Precautions and Complications (Table 49.2)

- Ensure that laser is fully functional.
- If the infant is at high risk for an adverse event that would terminate treatment prematurely, treat the more advanced eye first (assuming both have threshold ROP).
- Discontinue feedings at least 4 hours before the procedure, or empty the stomach with an orogastric tube.
- Establish intravenous access for infusions of medications and intravenous fluids.
- Observe transcutaneous or saturation monitor carefully, and adjust administered oxygen appropriately.
- Stabilize the infant: Correct electrolyte imbalances, platelet deficiency, etc.
- Use only 1% phenylephrine if there is a history of hypertension.

TABLE 49.2 Complications of Laser for Retinopathy

Complication	Treatment/Action
Systemic: intra- and immediately postop	
Bradycardia	Interrupt treatment. Assess airway, oxygen delivery. Atropine 0.1 mg IV
Hypoxia/cyanosis	Evaluate airway. Administer supplemental oxygen.
Apnea	Evaluate airway. Gentle stimulation. Administer supplemental oxygen. Hand-ventilate (self-inflating resuscitation bag, face mask).
Tachycardia	Assess pain control. Administer additional analgesic. Monitor blood pressure and perfusion.
Hypertension	Assess pain control. Administer additional analgesic. If moderate, observe. If severe, consider hydralazine 0.1 mg/kg IV
Arrhythmia	Manage as appropriate for arrhythmia.
Seizure (mechanism uncertain:? anticholinergic effect)	Supportive care. Phenobarbital.
Ocular: intraop	
Closure of central artery	Relieve pressure on globe (stop scleral depression).
Corneal clouding/abrasion	Rinse with balanced salt solution/saline. Interrupt treatment.
Retinal/vitreous/choroidal hemorrhage	Gentle pressure on globe (until arterial pulsations visible). Avoid lasering blood. May have to terminate treatment if extensive.
Ocular: postop	
Conjuntival hemorrhage	Observation.
Conjunctival laceration	Antibiotic ointment t.i.d. for 3â€“4 d.
Corneal abrasion	Antibiotic ointment t.i.d. for 3â€“4 d. Follow with slit lamp exam with fluorescein.
Hyphema	Topical cycloplegic and steroids. Follow intraocular pressure closely. Consider washout if high pressure, no resolution in 7-10 d.
Retinal/vitreous/choroidal hemorrhage	Close follow-up.
Ocular: late	
Amblyopia, strabismus, myopia	Pediatric ophthalmology assessment 3â€“4 mo after treatment(s). Educate parents prior to discharge re: need for regular ophthalmology follow-up.

IV, intravenously; t.i.d., three times per day.

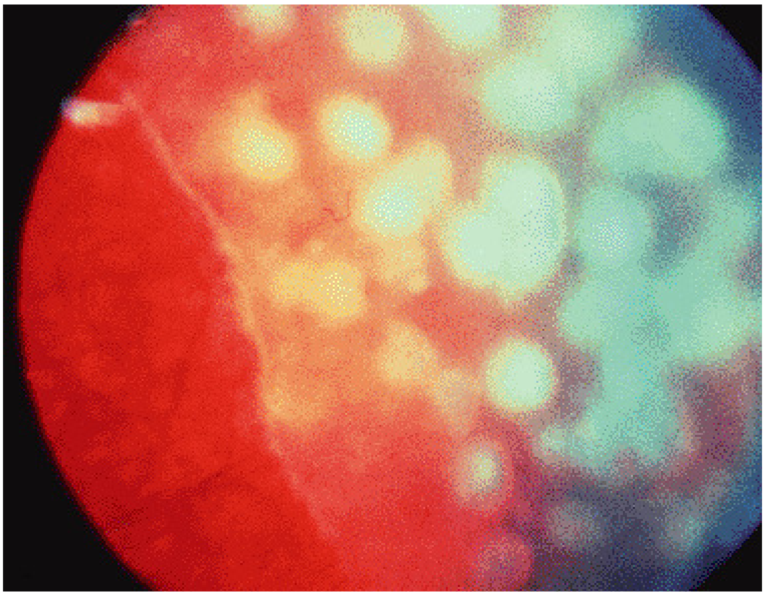

FIG. 49.5. Freshly lasered avascular retina.

- Wipe off any excess drops spilling onto the skin to avoid transcutaneous absorption (skin vessel blanching occurs with phenylephrine).

G. Technique

- General preparation
    - Instill eyedrops (per orders from ophthalmologist) into both eyes in the hour prior to procedure. Maximal dilation is critical for optimum laser; therefore, several (three or four) instillations of drops may be required, especially in eyes with neovascularization/vascular engorgement of the iris.
    - Transport the patient to surgical suite or designated procedure room in the nursery.
    - Ensure monitors are attached and functioning.
- Immobilize infant: Swaddle in a clean towel or blanket to immobilize arms and legs.
- Ensure that the intravenous tubing is accessible.
- Administer intravenous sedation.

  If local anesthesia is to be used, a combination of topical (e.g., tetracaine, proparacaine) and systemic analgesic/sedative e.g. intravenous morphine, medications is administered prior to injection.

- Distribute laser safety goggles and dim overhead lights.
- Retract lids.
- Perform laser: Cover the avascular retina with confluent gray-white burns (Fig. 49.5).
- Have an assistant count and record the number of spots and the duration and power of each spot.

H. Postoperative Care

- Instill 0.25% scopolamine hydrobromide in treated eye(s) daily for 3 to 5 days.
- Apply antibioticâ€“steroid preparation (e.g., tobramycinâ€“dexamethasone) to treated eye(s) three to four times daily for 5 to 7 days.
- Monitor the patient with a cardiorespiratory monitor for 24 to 72 hours.
- Perform a dilated retinal exam 1 to 2 weeks after treatment.
- If opaque media are present at the time of laser, or if the pupil does not dilate adequately, complete treatment of the avascular retina may be impossible, and â€œskip areasâ€□ may be visible in the

weeks after treatment. Treatment of these areas should be considered if there is not marked resolution of the adjacent plus disease and/or neovascularization.

- Follow the infant every 1 to 2 weeks until the ROP resolves completely. If at the time of discharge ROP is still present, ensure that the parents and the physicians responsible for the care of the infant after discharge are aware of the extreme importance of maintaining a regular schedule of outpatient examinations. Once the ROP has resolved completely, the baby should be seen by a pediatric ophthalmologist within 1 to 2 months to assess vision, ocular alignment and motility, refractive status, etc. Long-term follow-up over several years may be necessary (9,10,11 and 12).

I. Postdischarge Care

A critical component of treatment is post-discharge care. It is imperative that infants who develop any stage of ROP, especially those with prethreshold stage 3 or those that have received treatment, are seen within 1 to 2 weeks of discharge, or as directed by the ophthalmologist involved in the baby's care. No baby with any ROP, or who has regressed ROP after treatment, should leave the neonatal intensive care unit (NICU) without a scheduled follow-up examination.

A careful, reproducible tracking system for arranging follow-up should be established by every NICU. A member of the staff of each NICU should be responsible for maintaining and periodically auditing this system.

Verbal and written instructions for follow-up should be given to the parents. Parents should be given a discharge form indicating their baby's scheduled follow-up among their discharge instructions. The importance of scheduled follow-up should be prominently stated on the form.

J. Outcome

The benefit of ablative therapy for threshold ROP became apparent so quickly that enrollment for the CRYO-ROP study was halted after approximately half the planned number of infants were enrolled. The risk of adverse outcome (retinal detachment, macular fold) was cut in half in treated eyes.

Subsequently, as indirect argon and diode laser became available in the mid-1990s, the risk of adverse outcome in Zone II and III disease was reduced by another 50% (7,10). The outcome for eyes with Zone I disease, although poor, has improved with laser and incisional surgery (vitrectomy). Specifically, laser treatment of the posterior avascular retina can be accomplished easily and without necessitating conjuctival incisions, as in cryotherapy.

Treated eyes carry a risk of retinal dystopia, and myopia, and subsequent strabismus and amblyopia (11,12 and 13). To minimize the effect of refractive errors and strabismus, careful follow-up by a pediatric ophthalmologist is mandatory.

Premature infants are at risk for intracranial pathologies that may limit visual function. Pediatric ophthalmologists, neurologists, and others involved in the care of former preemies should be in frequent contact in order to address the often complex and changing visual deficits present in these children.

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50-Peritoneal Dialysis

Kathleen A. Marinelli
Majid Rasoulpour

Acute Peritoneal Dialysis (1,2,3,4, and 5)

In neonates, acute peritoneal dialysis (PD) is frequently preferred over hemodialysis (HD), continuous arteriovenous hemofiltration with or without dialysis (CAVH/D), and continuous venovenous hemofiltration with or without dialysis (CVVH/D) because it is technically easier. Because peritoneal surface area per kilogram of body weight is relatively larger in newborns and children than in adults, peritoneal dialysis usually allows adequate clearance and removal of excess fluid (6); in addition, it avoids the need for anticoagulation and maintenance of adequate vascular access (7).

A. Indications

- Renal failure, when conservative management has failed to adequately control any of the following conditions (8,9):
  - Hypervolemia
  - Hyperkalemia
  - Hyponatremia
  - Refractory metabolic acidosis
  - Hyperphosphatemia
  - Azotemia
  - Additional fluid space needed for delivering drugs and/or nutrition
- Inherited disorders of organic and amino acid metabolism when HD or CVVH/D is unavailable (10,11)

  - In hyperammonemic metabolic crisis, evidence suggests that ammonia is more efficiently removed by extracorporeal techniques than by PD (12).
  - In babies with imminent or current intracranial hemorrhage, PD is considered the therapeutic option of choice, especially in nonhyperammonemic disorders (12).

B. Relative Contraindications

- Acute abdomen
- Abdominal adhesions
- Immediately after abdominal surgery (13)
- Diaphragmatic or abdominal wall disruptions

C. Equipment (Figs. 50.1, 50.2 and 50.3)

- Masks, sterile drapes, gowns, and gloves
- Povidoneâ€“iodine
- 1% xylocaine without epinephrine
- 3-mL syringe with 25-gauge needle
- Intravenous cutdown tray with no. 11 surgical blade
- Waterproof tape
- 22-gauge angiocatheter
- A temporary catheter such as a 14-gauge angiocatheter or one of the commercially available temporary dialysis catheters, e.g., a Trocath (Trocath Peritoneal Dialysis Center, Kendall McGaw Laboratories, Sabana Grande, Puerto Rico)
- Dialysis solution (1.5, 2.5, or 4.25%)
  - Other concentrations can be made by manual mixing of standard solutions
- Heparin
- Home Choice Automated PD System (Fig. 50.2) or any other reliable fluid warmer
- IV pole
- Inline burette set
- Ultra Set CAPD Disposable Disconnect Y-Set
- MiniCap Extended Life PD Transfer Set With Twist Cap
- FlexiCap Disconnect Cap with povidoneâ€“iodine solution
- Medicap with povidoneâ€“iodine solution
- Baby weigh scale with low resolution (Medela, which has a resolution of 2 g from 0 to 6,000 g) (Fig. 50.2)

An alternative approach is to utilize a pediatric cycler set. Experience in using this equipment is necessary. We recommend a commercially available cycler that provides a minimum fill volume of 50 mL with 10-mL increments.

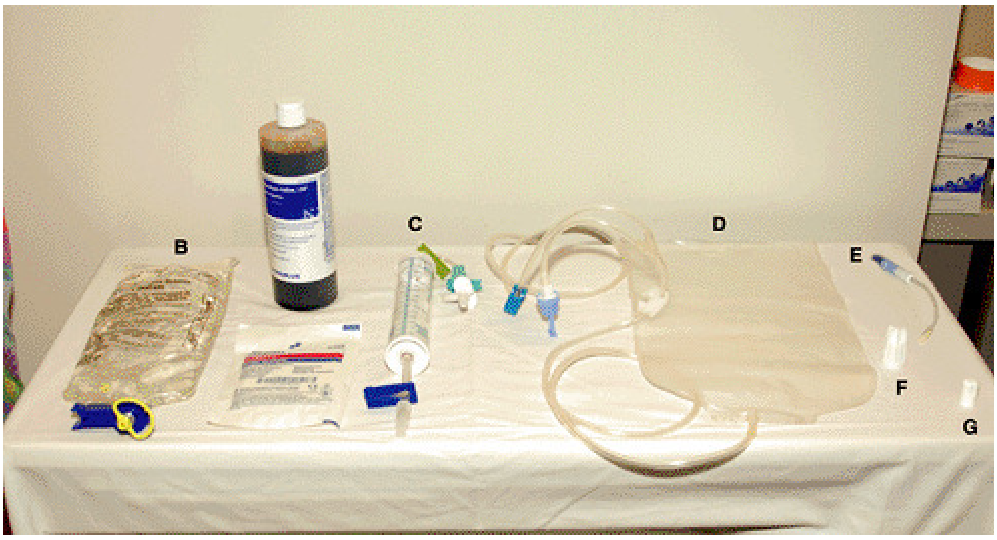

FIG. 50.1. A, IV pole (Fig. 50.3); B, Dianeal PD-2 Peritoneal Dialysis Solution (Baxter Healthcare Corporation, Deerfield, IL, USA); C, Inline Burette Set 150 mL (Abbott Laboratories, North Chicago, IL, USA); D, Ultraset CAPD Disposable Disconnect Y-Set (Baxter Healthcare Corporation, Deerfield, IL, USA); E, MiniCap Extended Life PD Transfer Set With Twist Clamp (Baxter Healthcare Corporation, Deerfield, IL, USA); F, Flexicap Disconnect Cap with Povidoneâ€“Iodine Solution (Baxter Healthcare Coporation, Deerfield, IL, USA); G, Minicap with Povidoneâ€“Iodine Solution (Baxter Healthcare Corporation, Deerfield, IL, USA).

D. Preprocedure Care

- Obtain informed consent.
- Check body weight and abdominal girth.
- Check for infection at the insertion site.
- Decompress the stomach.
- Catheterize the bladder.
- Place preweighed diaper under the patient.

Before assembly of system, wash hands and put on a mask. All connections should be made using sterile technique. Universal precautions should be observed (Chapter 4). Keep all tubing clamped. See Fig. 50.3 for connections.

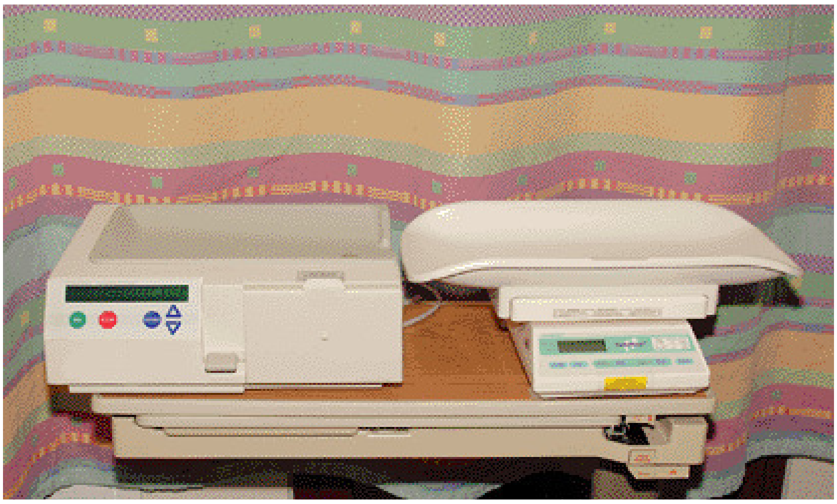

FIG. 50.2. Right: Home Choice Automated PD System (Baxter Healthcare Corporation, Deerfield, IL, USA). Left: Medela baby weigh scale (Medela, McHenry, IL, USA).

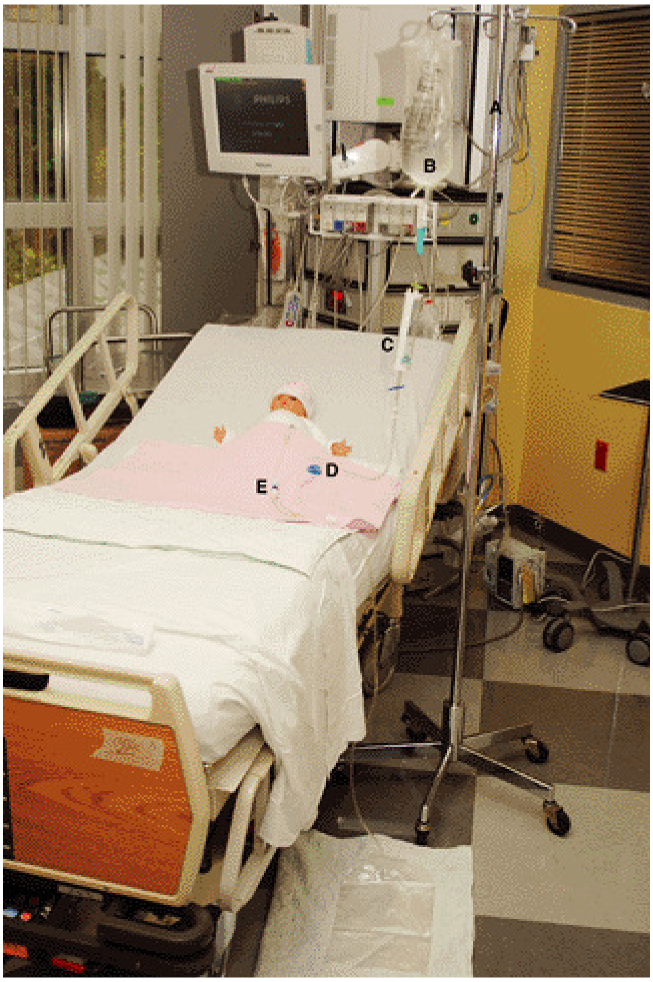

FIG. 50.3. An assembled peritoneal dialysis circuit illustrates an IV pole (A) and an in-line burette (C) that is connected to an Ultra Set CAPD Y-Set (D). The short limb of this Y-Set is connected to the transfer set (E), which is connected to a Tenckhoff catheter exiting from the abdominal cavity of a doll, and its long limb has a bag at its end that is located on the floor.

- Add 500 U of heparin to each 1 L of the dialysis solution. Start with 1.5% dialysate.
- Warm a liter bag of dialysate (Dianeal or other), or a larger bag if 1 L dialysate is not unavailable, by resting it on the heating surface of the Home Choice Automated PD System, or a reliable fluid

warmer. The temperature can be set between 35Â°C and 37Â°C. For a newborn, keep the temperature at 37Â°C (in older pediatric patients, the temperature is usually set to 36Â°C, and occasionally to 35Â°C if the environmental temperature is high).
- Spike the in-line burette set (Abbott Laboratories, North Chicago, IL, USA) into the dialysate (Dianeal or other) when the ideal temperature has been achieved.
- Connect the outlet of the burette set to the inflow line of the Ultra Set CAPD Disposable Disconnect Y-Set.
- Connect the short arm end of the Y-Set to the twist clamp end of a MiniCap Extended Life PD Transfer Set with Twist Clamp (Baxter Healthcare Corporation, Deerfield, IL, USA). If the catheter is placed surgically, this Transfer Set is routinely connected by most surgeons to the Tenckhoff catheter, before assessment of patency, and you will be able to skip this step.
- Prime the circuit in a sterile fashion, clamp, and cap the end of the transfer set, or the short limb of the Y-Set.

E. Procedure (Also Refer to Chapter 25, Abdominal Paracentesis, and Videos on Procedures DVD.)

The ideal technique is surgical insertion of a permanent peritoneal dialysis catheter, which can be placed in the neonatal intensive care unit (14). The catheter is tunneled from the peritoneum to an exit site on the skin; it usually works well and leaks infrequently (Quinton Pediatric Tenckhoff Neonatal 31 cm^2 Cuff catheter. Kendall Healthcare, Mansfield, MA, USA). However, if surgical insertion of a permanent catheter is not possible, an alternative approach is to utilize an angiocatheter or a temporary PD catheter for no longer than a few days. Note that surgically inserted catheters are associated with fewer acute complications (15). With catheters inserted at the bedside, guidewire-inserted femoral catheters have shown the least mechanical complications; intravenous catheters produce more mechanical complications than femoral catheters, but less than stylet catheters (16,17).

- Monitor vital signs.
- Restrain infant in supine position.
- Scrub.
- Prepare the skin of the abdomen (Chapter 4).
- Drape to expose the insertion site.

  The choice of insertion site is influenced by the preference of the physician and/or the presence of postoperative wounds, abdominal wall infection, or organomegaly. A location one third the distance from the umbilicus to the symphysis pubis in the midline or a site lateral to the rectus sheath in either of the lower quadrants is preferred.

- Infuse approximately 0.5 mL of xylocaine around the insertion point.
- Select either a 14-gauge angiocatheter or a temporary dialysis catheter.
- If you elect to use a 14-gauge angiocatheter:
  - Insert the angiocatheter at the insertion site.
  - Remove the stylet.
  - Infuse ~20 mL of normal saline to confirm a free flow. Clamp.
  - Proceed to Step 10 (Section E).
- If using a soft and flexible temporary catheter, such as a Cook catheter (Cook Critical Care, Bloomington, IN, USA), follow the manufacturer's instructions. Then proceed to Step 10 (Section E).
- Test patency.
  - Temporary catheter:
    - May observe flow of a few drops of saline. Connect the free end of the Transfer Set to the catheter.
    - Allow approximately 30 mL of dialysis solution to enter peritoneal cavity by gravity.

    - Clamp the short arm of the Y-Set (inflow).
    - Unclamp the long arm of the Y-Set (outflow).
    - Repeat steps a(2) through a(4) several times.
    - Secure the temporary catheter with a purse-string suture and tape if inflow and outflow occur readily.
  - Tenkhoff catheter:
    - Unclamp the Transfer Set. Will observe either saline or dialysis fluid, which was instilled at surgery, draining. Allow to drain to completion. Connect the short arm of the Y-Set to the Transfer Set.
    - Follow steps a(2) through a(5) of Step 10 above.

      This procedure (Step 10) usually results in a positive fluid balance (the volume drained is less than the volume infused). This retention is acceptable.

F. Management

- Establish a cycle time. This is usually about 60 minutes and consists of a fill by gravity, dwell time of 45 minutes, and drain by gravity.
- Establish a dialysis volume per pass. Starting volume is usually 20 to 30 mL/kg.
- Clamp the long arm of the Y-Set (outflow line).
- Unclamp the inflow line.
- Allow the dialysate to flow in as quickly as possible while carefully observing vital signs.
- Clamp the inflow line.
- Allow the fluid to dwell.
- Unclamp the outflow when dwell time is completed.
- Allow 5 to 10 minutes for draining.
- Clamp the outflow line.
- Repeat the cycle.
- Increase the volume by 5 mL/kg/cycle slowly. Maximum volume is 40 mL/kg if tolerated, attained over 12 to 24 hours.
- Continue to add 500 U of heparin/L of dialysate, until dialysate effluent return is clear, with no evidence of cloudiness.
- Add 3 mEq/L of K if serum K level is 4 mEq/L.

G. Monitoring

- Maintain hourly PD flow sheet.
  - Volume in
  - Volume out
  - Net/hr (+/-)
  - Net over the course of dialysis (+/-)
  - Intakes (enteral, parenteral)
  - Outputs (urine, gastric, insensible water loss, etc.)
- Establish a desired fluid balance. Proceed gently if negative balance is required. Reassess the state of hydration frequently.
- Measure serum glucose and potassium every 4 hours for the first 24 hours or until stable, then twice a day. Obtain other serum electrolyte levels twice daily. Check blood urea nitrogen, serum creatinine, serum calcium, serum phosphorus, and serum magnesium once a day.
- Obtain cell count, Gram stain, and culture of peritoneal effluent every 12 hours.
- Recognize that some drug dosages may need adjustments (18,19 and 20) (see Appendix E).

H. Complications

See Table 50.1.

Continuous Arteriovenous Hemofiltration in Newborns

A short discussion of CAVH and CVVH is included for completeness. However, use of these modalities should be limited to regional centers and performed by those with the required expertise.

TABLE 50.1 Complications of Peritoneal Dialysis

Problem (Risk)	What to Do
Perforation of bladder, bowel, or major vessels (3%â€“7%)	Surgical consultation
Puncture-site bleeding (3%â€“15%)	Apply pressure gently. Purse-string suture.
Blood-stained dialysis maintained after several cycles	Check hematocrit frequently. Continue heparin. Rule out major-vessel bleeding.
Leakage from exit site (2%â€“20%)	Reduce dwell volume until leakage stops.
Extravasation of dialysate into the anterior abdominal wall	Replace with new catheter.
More than 10% of solution retained in each of several consecutive cycles (outflow obstruction) (15%â€“30%)	Reposition infant gently. Reposition catheter by rotation and slight retraction. Do not advance. Remove if unchanged. Replace with new catheter.
Two-way obstruction (3%â€“20%)	Irrigate catheter with small amount of dialysate or saline aseptically. Reposition. Remove if unchanged.
Dislodgment of catheter (3%)	Replace with new catheter.
Hydrothorax (0%â€“10%)	Reposition infant, head and chest above level of abdomen. Decrease dwell volume.
Hyperglycemia (10%â€“60%)	Avoid high concentrations of dialysate unless outflow is inadequate. Low dose of insulin if needed.
Lactic acidosis	Use bicarbonate dialysate[a]
Hyponatremia	Reduce fluid intake. Aim to increase outflow if secondary to fluid overload.
Hypernatremia	Increase fluid intake if secondary to excessive ultrafiltrate.
Exit site infection (4%â€“30%)	Systemic antibiotics.
Peritonitis (0.5%â€“30%)	Several rapid flushing exchanges. Blood culture. Systemic vancomycin plus ceftazidime or an aminoglycoside. For fungal peritonitis, systemic therapy is needed and catheter should be removed.
Hernia (inguinal or umbilical) (2%â€“13%)	Possible need for future repair.
Small bowel herniation and gangrene at catheter exit site (1 case report)	Surgical consultation
Removal of therapeutic drugs	See Appendix E.

[a] 1.5% bicarbonate dialysis solution: 140 mEq/L Na, 110 mEq/L Cl, 30 mEq/L HCO3, 15 g of glucose; add sterile water to 1,000 mL.

Data from refs. (4,15,16,21,22,23,24,25,26,27,28,29,30,31).

CAVH is an extracorporeal technique for removing plasma water and its dissolved solutes of less than 50,000 Da over an extended period of time. With use of an arterial access line of the largest possible diameter and a venous access line, blood enters the extracorporeal circuit (arterial tubing, hemofilter, and venous tubing) by way of the arterial line and returns to the patient by way of the venous line (Fig. 50.4). The arteriovenous pressure gradient frequently produces adequate blood flow through the circuit; however, the addition of a blood pump may be necessary. As blood flows through the extracorporeal device, plasma water and dissolved solutes are filtered out (ultrafiltered) through the pores of a hemofilter. A hemofilter is composed of many fine capillaries of highly water-permeable membranes located within a cylindric case. The filtered-off fluid (ultrafiltrate) is drained out by way of an exit incorporated on the surface of the hemofilter. The fluid removed has all the characteristics of an ultrafiltrate of plasma water.

Within the past few years, except when it is incorporated in an extracorporeal membrane oxygenation circuit for ultrafiltration, CAVH has been widely replaced by CVVH. Two single-lumen catheters (or one double-lumen venous catheter) are used for vascular access in CVVH. Blood flow is maintained by a pump and is therefore independent of the patient's systemic blood pressure. Several brands of CVVH machines are currently available in many pediatric centers for CVVH/D (32).

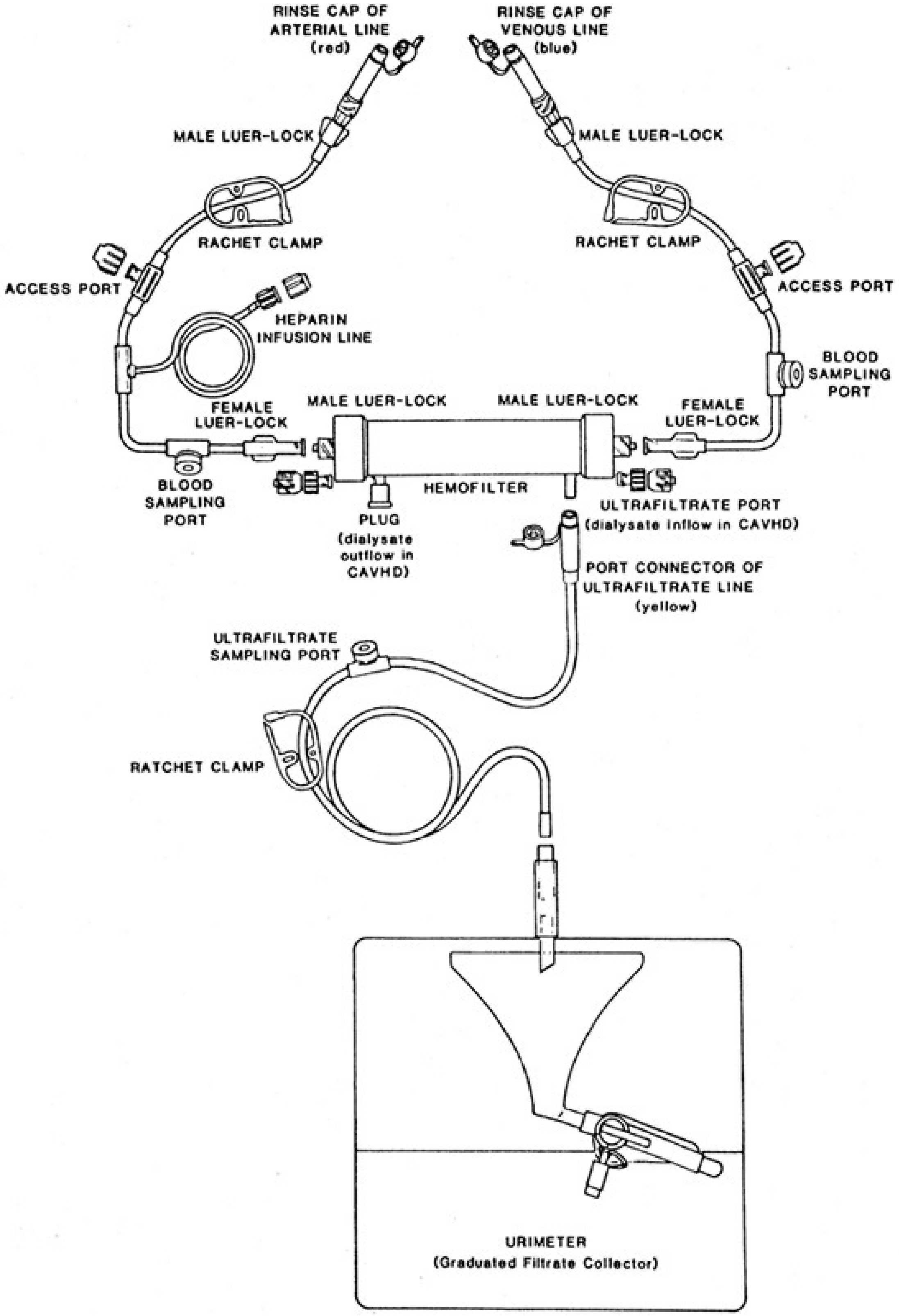
RINSE CAP OF ARTERIAL LINE (red)
RINSE CAP OF VENOUS LINE (blue)
MALE LUER-LOCK
MALE LUER-LOCK
RACHET CLAMP
RACHET CLAMP
ACCESS PORT
ACCESS PORT
HEPARIN INFUSION LINE
BLOOD SAMPLING PORT
FEMALE LUER-LOCK
MALE LUER-LOCK
MALE LUER-LOCK
FEMALE LUER-LOCK
BLOOD SAMPLING PORT
HEMOFILTER
PLUG (dialysate outflow in CAVHD)
ULTRAFILTRATE PORT (dialysate inflow in CAVHD)
PORT CONNECTOR OF ULTRAFILTRATE LINE (yellow)
ULTRAFILTRATE SAMPLING PORT
RATCHET CLAMP
URIMETER (Graduated Filtrate Collector)

FIG. 50.4. A continuous arteriovenous hemofiltration circuit.

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51-Neonatal Hearing Screening

Rachel St. John
Susan H. Morgan

A. Definitions

- Otoacoustic emissions (OAE): A screening tool that measures sounds generated by a functioning cochlea. A probe containing a microphone delivers a sound stimulus into the ear and records the response that travels back out of the cochlea, through the middle ear, and into the ear canal.
- Automated auditory brainstem response (AABR): A screening tool that records auditory brainstem responses and compares them to a template representing typical results in neonates. Click sounds are delivered by earphones into the ear canal, and electrodes placed on the head and nape of neck register the auditory brainstem response. In addition to assessing middle ear and cochlear activity, this test evaluates the function of the auditory nerve and auditory brainstem.
- Auditory brainstem responses (ABR); may also be referred to as brainstem auditory evoked response (BAER): A diagnostic test used to predict type and severity of hearing loss. ABR testing is conducted after a failed screening measurement. Auditory brainstem responses are determined in each ear for both click and tone stimuli. These sounds are presented by air (earphone) as well as bone conduction. Severity of hearing loss is expressed in decibels and described as conductive, sensorineural, or mixed.

B. Purpose

- Identifying and providing early intervention for children with congenital hearing loss to minimize delay in speech and language development.
- Supporting accurate reporting by state of incidence of congenital hearing loss.

C. Background

- The incidence of congenital hearing loss in the general population is approximately 2 to 4 in 1,000 live births in the United States (1).
- The risk for hearing loss can increase substantially when infants are exposed to known perinatal risk factors for hearing loss, such as TORCH infections, significant hyperbilirubinemia, and ototoxic medications. As technology improves and the number of at-risk infants graduating from neonatal intensive care nurseries rises (2), the need for early identification of hearing loss and intervention becomes even more critical.
- Any infant who fails hearing screening needs to be immediately referred to a pediatric audiologist. Delaying diagnosis of hearing loss can lead to significant problems in language and speech acquisition. The Centers for Disease Control Early Hearing Detection and Intervention Program recommends that infants identified by a failed hearing screen be referred for a comprehensive audiology evaluation as soon as possible, and always before 3 months of age.

D. Indications

- Ideally, every newborn should receive a hearing screen before discharge from the hospital. In 1993, the National Institutes of Health (NIH) Consensus on Early Identification of Hearing Loss concluded that all infants should be screened for hearing impairment prior to hospital discharge, if possible (3). The American Academy of Pediatrics officially endorsed these recommendations in 1999.

Over the past 13 years, widespread support has led to state-mandated or state volunteer programs throughout the United States. Currently, 39 states and the District of Columbia have passed legislation mandating universal newborn hearing screeningâ€”that is, hearing screening for every infant, regardless of background and risk factors (4).

- Infants who meet high-risk criteria for acquiring hearing loss warrant immediate hearing screening, as well as ongoing monitoring. Table 51.1 lists factors known to contribute to neonatal hearing loss (5). It is critical that infants with any of these risk factors be referred to audiology after discharge, even if they have passed their initial hearing screen, in order that they may continue to be monitored during the years of initial language acquisition and development.

TABLE 51.1 High-Risk Registry to Screen Selectively for Hearing Loss

- Illness or condition that requires admission of 48 hours or longer to neonatal intensive care unit
- Stigmata or other findings associated with a syndrome known to include sensorineural or conductive hearing loss
- Family history of permanent childhood sensorineural hearing loss
- Craniofacial anomalies, including those with morphologic abnormalities of the pinna and ear canal
- In utero infection, such as cytomegalovirus, herpes, toxoplasmosis, or rubella
- Parental or caregiver concern regarding hearing, speech, language, and developmental delay
- Postnatal infections associated with sensorineural hearing loss, including bacterial meningitis
- Neonatal indicators, specifically hyperbilirubinemia at a serum level that requires exchange transfusion, persistent pulmonary hypertension of the newborn associated with mechanical ventilation, and conditions that require the use of extracorporeal membrane oxygenation
- Syndromes associated with progressive hearing loss, such as neurofibromatosis, osteopetrosis, and Usher syndrome
- Neurodegenerative disorders, such as Hunter syndrome, or sensory motor neuropathies, such as Friedreich ataxia and Charcot-Marie-Tooth syndrome
- Head trauma
- Recurrent or persistent otitis media with effusion for at least 3 months

E. Contraindications

- Patient has significantly atretic or total lack of external ear canal: Refer directly to pediatric audiologist.
- Although it is certainly fair to rescreen an infant who has potentially failed screening because of excessive background noise, vernix in ear canal, etc., multiple rescreening attempts in hopes of eventually obtaining a â€œpassâ€□ are not recommended and can contribute to delayed identification of congenital hearing loss.

F. Limitations

- Infant hearing screening can be compromised by environmental noise (such as a busy intensive care unit) or infant movement. OAE screening, more so than AABR, is particularly affected by vernix occluding the ear canal, or middle ear pathology such as effusion (6).
- OAE screening, although less time-consuming to set up and conduct, has a higher â€œreferâ€□ (fail) rate than AABR. The refer rates for OAE screening alone have been cited in the literature as being between 5.8% and 6.5%, with refer rates using AABR screening around 3.2% (7,8). In particular, infants who are <48 hours old are more likely to have a â€œreferâ€□ result if screened with OAE, as the presence of vernix and debris in the ear canal can be a significant factor (9). There is no

standardization of newborn hearing screening protocols in the United States at this time, and both technologies are in wide use.
- It is difficult to state accurately how many infants who â€œfailâ€□ their hearing screen actually do hear normally (have a â€œfalse-positiveâ€□ result). This is due mainly to the fact that, for a variety of reasons, a significant number of patients who get a â€œreferâ€□ result do not follow up for diagnosis with an audiologist. The Joint Committee on Infant Hearing benchmark for diagnostic follow-up is 70%, and there are large programs that have shown steady improvement toward meeting or exceeding this standard (10,11). In sparsely populated areas of the country, where resources are limited, however, as many as 90% of infants requiring diagnostic assessment are lost to follow-up (12). Similarly, the number of infants who pass their hearing screen and ultimately end up with a diagnosis of hearing loss (â€œfalse-negativeâ€□ result) is difficult to assess. Children whose hearing loss is not present at birth but develops later on (â€œlate-onsetâ€□ or â€œacquiredâ€□ hearing loss) truly do pass their newborn hearing screenings. They are not â€œmissedâ€□ by screening: Their hearing loss is different in nature than hearing loss that is present at birth (13).

G. Equipment

- An OAE screening system consists of a miniature microphone housed in a probe that emits either click or tone stimuli. This assembly is coupled to a computer for analysis of the sound in the ear canal and processing of the otoacoustic emission. Results may be automatically analyzed and interpreted as either â€œpassâ€□ or â€œreferâ€□ for each ear. Figure 51.1 shows an infant undergoing OAE screening.
- An AABR screening system consists of occlusive earphones that cover the ears and emit sound stimuli.

  Electrodes placed on the head and the back of the neck detect electrical activity from the auditory nerve and brainstem. A computer registers samples of the electrical activity over a fixed period of time. The averaged responses are then compared to a normal newborn template to determine if the result is a â€œpassâ€□ or a â€œreferâ€□ for each ear. Figure 51.2 shows an infant undergoing AABR screening.

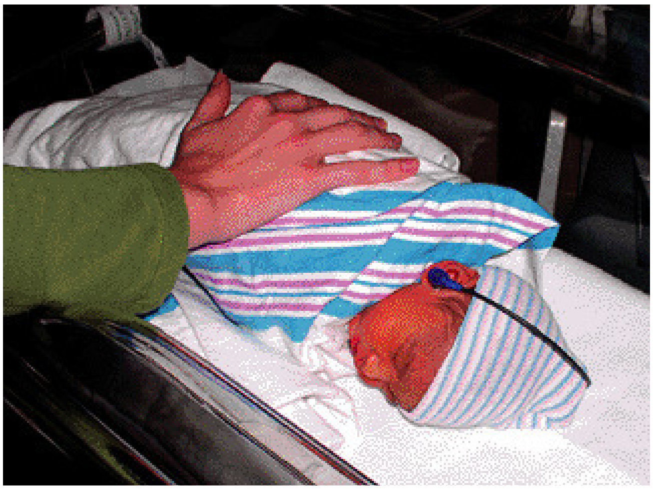

FIG. 51.1. An infant undergoing OAE screening.

H. Precautions

Care should be taken to attempt screening in a relatively quiet environment, as well as ensuring that the infant is resting comfortably and the ear canals are free from obvious debris.

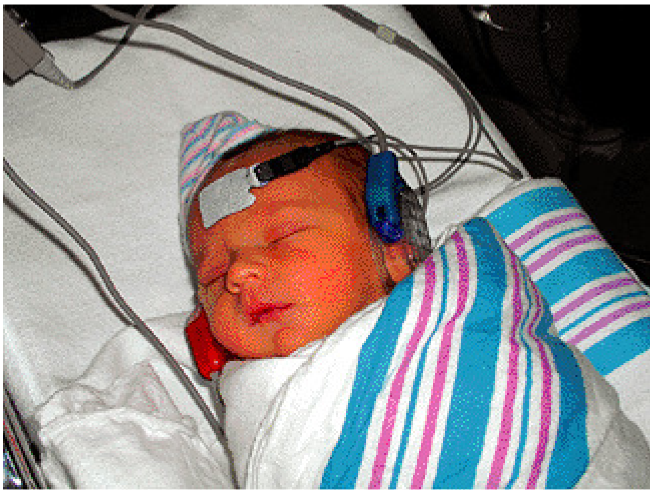

FIG. 51.2. An infant undergoing AABR screening.

I. Special Circumstances

- Hearing parents whose infant does not pass a hearing screening: Parents are often quite concerned to learn that their infant has not passed a hearing screening. This can be especially stress-provoking for parents whose infant may have spent a good deal of time in a neonatal intensive care unit (NICU) and may be facing additional medical concerns upon discharge. It is extremely important to remember that a failed hearing screening is not a definitive diagnosis of hearing loss. It is an important indicator that the infant needs immediate referral to an audiologist for further detailed evaluation, which may or may not result in a formal diagnosis of hearing loss.
- Deaf parents whose infant does not pass a hearing screen: Deaf parents, especially culturally Deaf individuals who use American Sign Language and identify strongly with being members of the Deaf community, are often thrilled to find out that their infant may have hearing loss. This is a cultural identification: These parents are rejoicing in the fact that their infant is like them and will have a cultural place of significance in their social world. This is often in direct opposition to the traditional medical perspective on hearing loss (as a pathology that needs to be addressed and â€œfixedâ€□), and the parental reaction can be frankly shocking for involved health care professionals. It is very important to realize that these infants of culturally Deaf parents are not facing the immediate crisis of delayed language development referred to earlier. American Sign Language is a well-researched, intact language (14,15) that is immediately accessible to an infant of Deaf parents. Although it is still extremely important to establish audiologic follow-up for these infants of Deaf parents who fail a hearing screen, it is also critical to respect the potential cultural implication for such families. These parents may be celebrating in a manner very similar to hearing parents who are happy that their infant has passed the hearing screening.

J. Techniques

Both OAE and AABR screening systems can be automated: An individual only needs to be appropriately trained to set up and apply the equipment. A computer processes the incoming information and gives a readout of the result, usually as pass or â€œrefer.

K. Complications

OAE and AABR are considered to be noninvasive and safe procedures. Like any procedure that involves the application of electrode pads, mild superficial skin abrasions could possibly occur with the removal of the electrode pads after AABR testing (16).

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52-Management of Natal and Neonatal Teeth

Priyanshi Ritwik
Robert J. Musselman

The occurrence of teeth in the oral cavity at birth or within the first 30 days of life is uncommon. Such teeth have been called natal and neonatal teeth, respectively. This distinction, however, is temporal and artificial. Relevant clinical inferences can be made by further describing these teeth as mature or immature based on the quality of dental tissue and degree of dental development (1). Hebling et al. classified natal teeth into four clinical categories (2) (Table 52.1).

The reported incidence of natal and neonatal teeth varies; a range of 1in 2,000 to 3,500 is widely accepted (3). However, in a study of 18,155 infants, the reported incidence of natal and neonatal teeth was 1:716 (4). About 85% of natal and neonatal teeth are mandibular incisors (5,6). However, there are case reports of natal teeth in the posterior regions of the alveolar process (3,7,8), thereby necessitating an examination of the posterior region of the alveolar processes at birth for the presence of teeth. Further, 95% of natal and neonatal teeth are a member of the normal complement of the deciduous dentition (9); this implies that supernumerary natal and neonatal teeth are rare. Hence natal and neonatal teeth should usually be retained.

A. Etiology

- Superficial positioning of the primary tooth germ (10)
- Infection and malnutrition (10)
- Febrile illness (10)
- Maternal exposure to toxins (polychlorinated biphenols, polychlorinated dibenzofuran, polychlorinated dibenzo-p-dioxin) (11)
- Syndrome/medical condition (Table 52.2) (10)

B. Clinical Presentation (Figs. 52.1,52.2,52.3 and 52.4)

There is variability in the presentation of natal and neonatal teeth. Although some have normal crown shape and color, and are held firmly in the alveolar process, others present as discolored microdonts with hypermobility. The latter are the immature type of teeth. The management of the patient depends on the clinical presentation.

C. Clinical Assessment

Clinical assessment should include an assessment of the tooth, oral soft tissues, and the systemic disposition of the patient.

- Dental assessment
    - Mobility: Tooth mobility >1 mm is usually an indication for the extraction of the natal/neonatal tooth.
    - Color and shape of tooth: Discoloration and abnormal morphology indicate an immature natal/neonatal tooth, which usually will require removal.
    - Root formation: This can be assessed with a dental radiograph. However, a loose tooth is likely to be lacking in root structure, and is likely to exfoliate spontaneously and early, with the risk of aspiration.
- Soft tissue assessment
    - Ventral surface of the tongue: Riga-Fede disease, although not a disease, is the term given to an ulcerative granuloma formed on the ventral surface of the tongue. It results from irritation of the tongue by the sharp margins of the mandibular incisor.
    - Gingival tissue: Gingival tissue adjacent to the natal/neonatal tooth should be examined for presence of inflammation or granulomatous lesion, caused by irritation by the sharp cervical margins of an immature tooth.
- General assessment:

    Table 52.2 lists the systemic conditions associated with higher incidence of natal/neonatal teeth. They should each be ruled out to ensure that a pre-existing medical condition is not overlooked.

D. Precautions

- Keep in mind that the initial question in management of natal teeth is whether extraction is indicated. Indiscriminate extraction of natal/neonatal teeth is discouraged (12).

TABLE 52.1 Hebling Classification of Natal Teeth

1. Shell-shaped crown poorly fixed to the alveolus by gingival tissue with absence of a root
2. Solid crown poorly fixed to the alveolus by gingival tissue with little or no root
3. Eruption of the incisal margin of the crown through the gingival tissue
4. Edema of gingival tissue with an unerupted but palpable tooth

- Natal and neonatal teeth should be differentiated from cystic lesions such as Bohn nodules and Epstein pearls, by palpation and location in the infant's mouth. Bohn nodules and Epstein pearls are firm and have a smooth, rounded surface. There will usually be several nodules/pearls, and they may be located on the posterior palate or mandibular ridge.

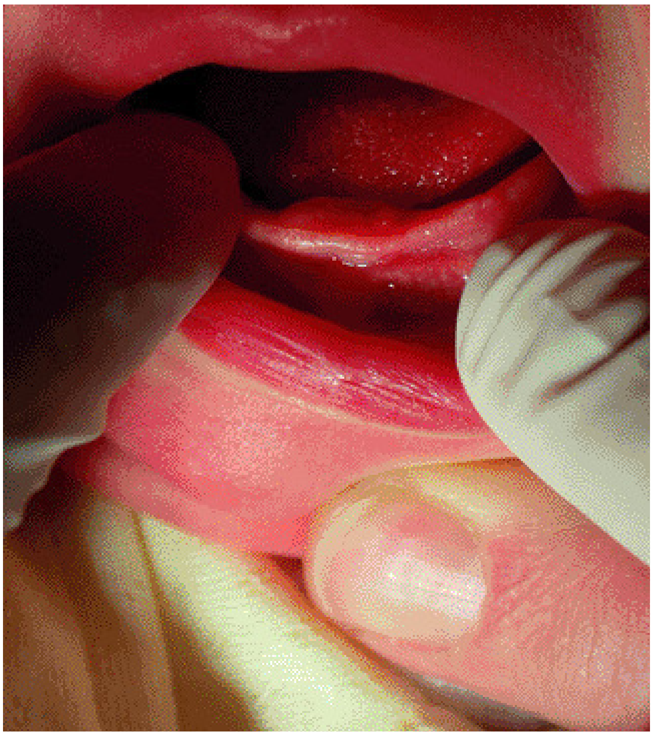

FIG. 52.1. Patient 1: Normal (edentulous) alveolar ridge in neonate.

- Prior to extraction, it must be confirmed that the patient has received the appropriate dose of vitamin K at birth (10). There has been one report of difficulty in achieving hemostasis by local pressure after the extraction of natal tooth. This patient received microfibrillar collagen hemostat over the extraction site (3). Current literature supports the extraction of the natal tooth at 10 days or later after birth, unless there is significant risk of aspiration (10).
- A detailed family history should be obtained, to rule out inherited coagulopathy.
- Following the extraction, the socket should be curetted to remove odontogenic tissue (see F, Complications).
- Long-term care: Whether the patient receives conservative restorative treatment or extraction, the parents should be encouraged to maintain regular dental appointments with a pediatric dentist. This enables monitoring of the extraction site, and parental guidance in oral hygiene practices for their infant.

TABLE 52.2 Conditions Associated with Higher Incidence of Natal/Neonatal Teeth

Ellis-Van Creveld syndrome
Hallerman-Streiff syndrome
Craniofacial synostosis
Multiple steacystoma
Congenital pachyonychia
Sotos syndrome
Cleft palate
Pierre Robin anomalad

E. Technique

Nonextraction case

If the tooth is firm and appears of normal color and shape, extraction is not indicated.

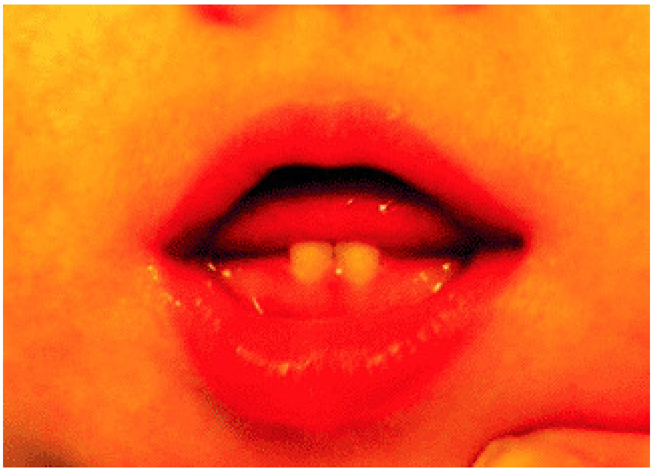

FIG. 52.2. Patient 2: Hebling Classification #3 neonatal tooth; not indicated for extraction.

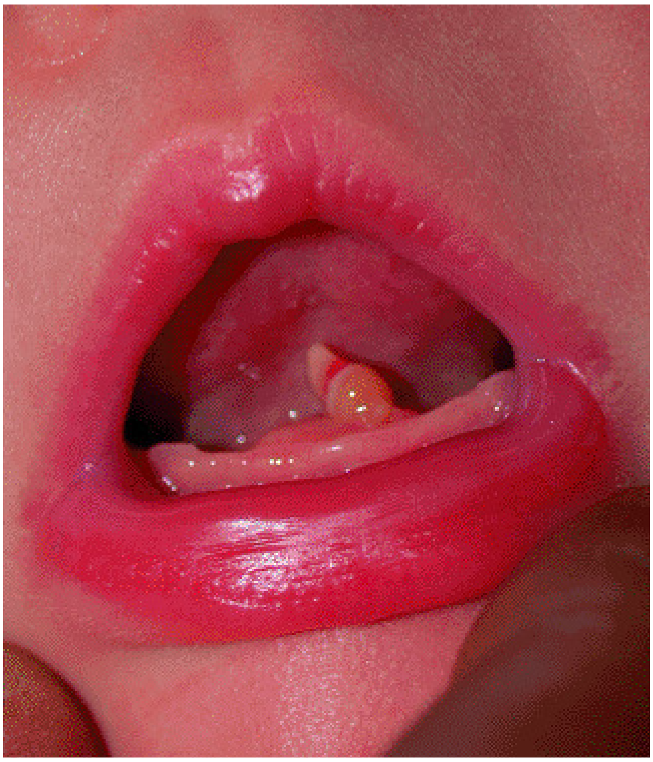

FIG. 52.3. Patient 3: Hebling classification #2 natal tooth; this tooth was extracted.

- Should the mother complain of discomfort while breast feeding, the use of a breast pump and bottling of milk should be encouraged.
- If the patient presents with Riga-Fede disease, a pediatric dentist should be consulted. The sharp margins of the tooth can be smoothed using photopolymerized dental composite restorative resin. This results in spontaneous resolution of the tongue lesion (13).
- Pain relief and faster healing may be accomplished by carefully applying Kenalog in Orabase (14).

Extraction Case

Extraction is indicated if there is hypermobility of the tooth, or if the tooth is of the immature type (malformed, discolored, lacking root development). These would be classified as class 1 or 2 by Hebling et al. (2).

- Equipment
    - 2 x 2-in gauze piece
    - Topical anesthetic
    - Blunt-nosed sterile surgical scissors
- Technique
    - Apply a tiny amount of topical anesthesia on the tissue attachment of the tooth.
    - Hold the tooth with 2 x 2-in gauze square with your fingers and gently remove the tooth.

      If the tooth has to be grasped with forceps, then the infant needs to be referred to a pediatric dentist for evaluation and possible extraction.

    - Blunt-nosed scissors can be used to cut the tissue if it is too fibrous.

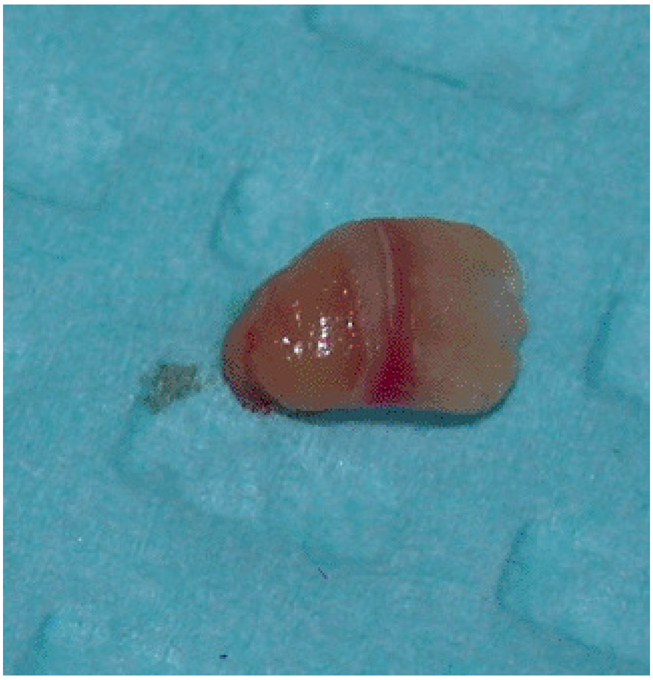

FIG. 52.4. Patient 3: The natal toothâ€”which was removed by grasping the tooth with gloved fingers holding the tooth with a 2 x 2-in gauze square.

F. Complications of Extraction

- Tissue tags comprising dental papilla and/or Hertwig's epithelial root sheath remain in the extraction socket (15). These tissues may continue to form dental hard tissues, that is, dentin and root structure (15). These aberrant dental hard tissues may interfere with the normal eruption of adjacent primary teeth (15).
- The development of postextraction pyogenic granuloma (16) and hamartoma (17) have been reported.

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53-Relocation of a Dislocated Nasal Septum

Smitha Warrier
Mhairi G. MacDonald

A. Indications

To avoid future surgery, breathing and feeding problems, epistaxis, malocclusion, and sinusitis (1)
Fetal compression sufficient to cause some degree of nasal deformation is a frequent physical finding on early newborn examination and normally resolves within 48 hours of birth (Fig. 53.1). In some instances, intrauterine forces or pressure applied during delivery cause a true septal dislocation (Fig. 53.2)Fig. 53.2). The incidence of true septal dislocation ranges from 1% to 4% of births (1,2,3,4,5,6 and 7). The otolaryngology literature indicates that septal dislocation should be relocated within a few days of birth for the best outcome (1,3,8). To differentiate compression deformity from true septal dislocation, apply gentle pressure to the tip of the nose; a dislocated septum will move farther from the midline at the base, a compressed septum will not move from the midline at the base. A compressed nose can be restored to normal anatomy with gentle pressure; a nose with septal dislocation cannot.
B. Contraindications

- Presence of other nasal or midline congenital anomalies requiring more extensive treatment
- Posterior septal dislocation
- Nasal orifice too small to easily admit smallest septal forceps

C. Equipment

- Septal forcepsâ€”modified Walsham or other appropriately sized septal forceps (Fig. 53.3).

D. Precautions

- Reduction should be performed within the first 3 to 4 days after birth.
- Otolaryngology evaluation for refractory dislocations or associated facial abnormalities
- Adequate restraint of infant, especially the head
- Remember that many newborns are obligate nasal breathers; insertion of a large-bore nasogastric tube into the stomach or an oral airway, prior to the procedure, will serve to separate the tongue from the palate and to promote oral respiration.

E. Technique

- Place septal forceps into the nares on the anterior aspect of the cartilaginous septum, posterior to columella. Advance blades gently, approximately 0.5 to 1.0 cm. Do not advance past the inferior aspect of the middle turbinate; do not force (Fig. 53.4).
- Gently close the forceps onto the septum.
- Direct the pressure of the lower edges of the forceps blades toward the midline, to move the septum into alignment with the nasal groove on the vomer (spine)â€”a slight upward motion may be required to lift the inferior border of the septum over the side of the vomer into the spinal groove (can be compared to replacing a sliding door into the slider) (Fig. 53.4B, C).
- Re-examine to ensure adequate reduction.

F. Complications

- Hemorrhage
- Damage to nasal structures, e.g., the turbinates, septum
- Damage to skull baseâ€”resulting in cerebrospinal fluid (CSF) leak (if speculum inserted too far)
- Persistent dislocation

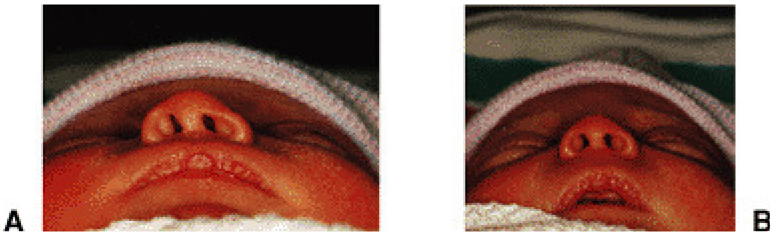

FIG. 53.1. Nasal compression without septal deviation. A: Shortly after birth, the nose is asymmetrical from simple compression with an angled septum at rest. B: The septum assumes its normal angle. (From Fletcher MA. Physical Diagnosis in Neonatology. Philadelphia: Lippincott-Raven; 1998:211.)

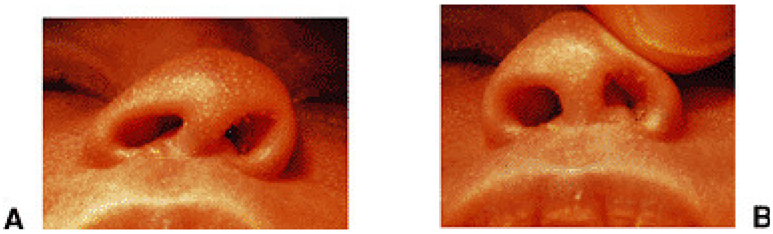

FIG. 53.2. A: At rest it is difficult to distinguish a true deviation. B: Attempts to restore normal anatomy are unsuccessful as the septum remains deviated at the base. (From Fletcher MA. Physical Diagnosis in Neonatology. Philadelphia: Lippincott-Raven; 1998:211.)

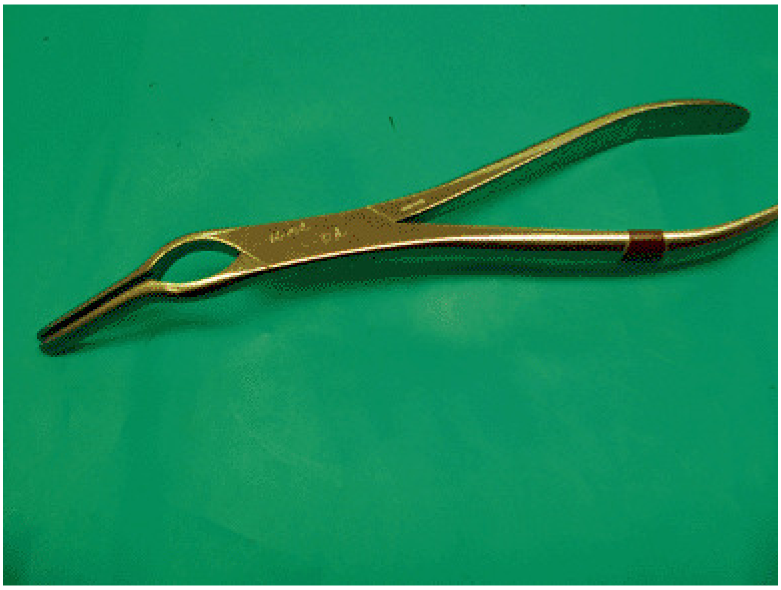

FIG. 53.3. Walsham septal forceps.

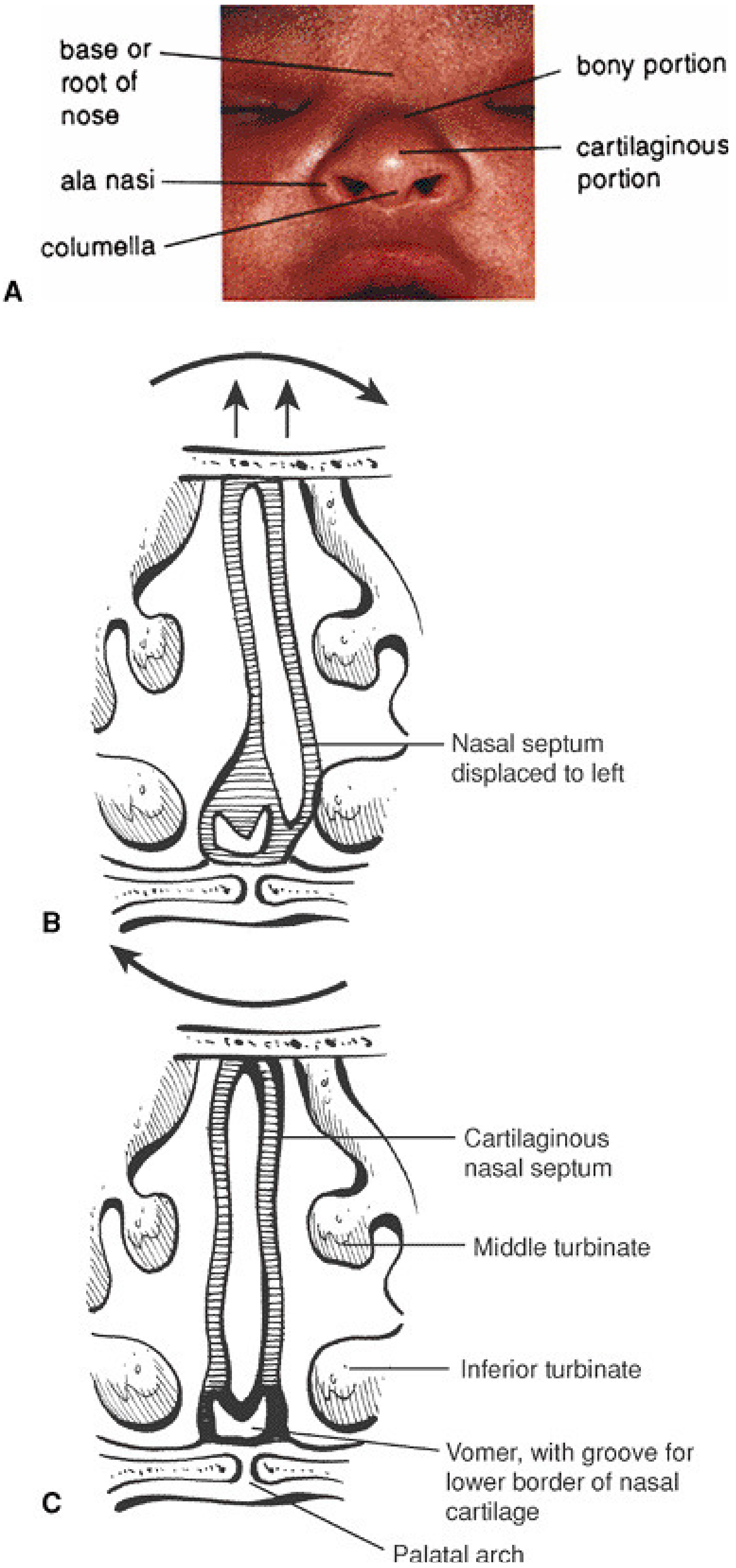
base or root of nose
bony portion
cartilaginous portion
ala nasi
columella
A
Nasal septum displaced to left
B
Cartilaginous nasal septum
Middle turbinate
Inferior turbinate
Vomer, with groove for lower border of nasal cartilage
C
Palatal arch

FIG. 53.4. A: Landmarks of nasal anatomy. (From)Fletcher MA. Physical Diagnosis in Neonatology. Philadelphia: Lippincott-Raven; 1998:210.) B: Shows the cartilagenous nasal septum displaced to the left from the ridge on the vomer. Large arrows indicate the direction of turn of the forceps blades needed to replace the septum into the groove; small arrows indicate the concurrent upward pull. C: Shows the septum postreplacement.

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54-Lingual Frenotomy

Kathleen A. Marinelli

A. Definitions

- Lingual frenulum a fold of mucosa connecting the midline of the inferior surface of the tongue to the floor of the mouth (1)

  Generally thin, membranous, and avascular in the newborn (Fig. 54.1)

- Ankyloglossia (tongue tie) a congenital oral abnormality, characterized by an abnormally short, thick, and/or tight lingual frenulum (1,2 and 3)
  - Ankyloglossia derives from the Greek agkylos crooked, and glossa tongue.
  - Many different variations of tongue tie
  - Differing degrees of severity
  - May restrict mobility of the tongue tip
- Lingual frenotomy (tongue clipping) a minor surgical procedure, appropriate for treatment of significant ankyloglossia in infants

  Can be accomplished at the bedside or in an outpatient clinic setting (4,5 and 6)

- Frenuloplasty or frenectomy more complicated surgical procedures employing Z-plasty technique or with removal of tissue
  - Reserved for older children, adults, or infants with a complicated lingual frenulum, such as a thickened frenulum containing genioglossus muscle
  - Performed in the operating room, by a surgeon, under conscious sedation or general anesthesia

B. Purpose

- Lingual frenotomy performed when the presence of ankyloglossia restricts or impedes an infant's ability to suckle successfully
  - Most common in breastfeeding infants
  - Occasionally seen in infants using an artificial teat
- Other problems related to ankyloglossia that may manifest in older children and adults (2,3,7,8,9,10 and 11).
  - Mechanical problems

    Gingival recession, mandibular diastema, malocclusion, prognathism, difficulty with intraoral toilet (licking the lips, sweeping food debris off teeth)

  - Articulation errors in speech
  - Social effects
    - Difficulty playing a wind instrument, licking an ice cream cone or lollipop, etc.
    - Can lead to social embarrassment and the need for the more complicated frenuloplasty procedure outside the neonatal period

C. Background

- There is much controversy surrounding ankyloglossia regarding:
  - Definitions
    - Range from vague descriptions of a tongue that functions with a less than normal range of activity to a specific description of a frenulum that is short, thick, muscular, or fibrotic (3) (Figs. 54.1 and 54.2)
    - A range of methods to describe and quantify tongue tie have been proposed, including methods of measuring the anatomic differences, to quantifying observations.
  - Clinical significance (1,2,6,12,13)
    - Prior to the introduction and widespread use of breast milk substitutes in the early twentieth century, breastfeeding was necessary for survival.
      - Release of tongue tie was commonly performed by the midwife at delivery (12,14).
      - Tongue tie does not generally pose a problem for the more passive process of bottle feeding.
      - With a decrease in breastfeeding rates, frenotomy became unnecessary.
    - With the current resurgence in breastfeeding, and increasing knowledge of the risks of breast milk substitutes, tongue tie is again emerging as an entity that interferes with successful breastfeeding.
    - A recent article surveying >1,500 pediatricians, otolaryngologists, lactation consultants, and speech pathologists concluded that there is little consensus among and within these groups regarding the significance or management of ankyloglossia (15).
  - Need for surgical intervention (2)
    - Some babies with tongue tie can breastfeed successfully with no surgical intervention (1,16).
    - Each breastfeeding dyad is a unique combination of many factors, including the infant's intraoral structures, adequacy of suckling, and the size, shape, and elasticity of maternal nipples.
    - An emerging body of literature suggests that for those motherâ€“baby dyads who are experiencing difficulty breastfeeding associated with the presence of tongue tie,

frenotomy is a safe, effective, and immediate means of providing relief of symptoms and supporting breastfeeding (12,13,16,17,18,19 and 20).
  - Timing of surgical intervention: To facilitate breastfeeding, it can be done in the first days of life, or anytime thereafter if problems emerge.
- Incidence of tongue tie ranges from 0.02% to 4.8% in various studies (1,2,11,15,17,20,21).
  - There appears to be a genetic predisposition in some families.
  - Most studies report approximately a 2:1 male predominance.
- In a recent study, 22% of 425 North American pediatricians surveyed indicated they had performed frenotomies; however, only 10% reported being taught the technique during residency (15).

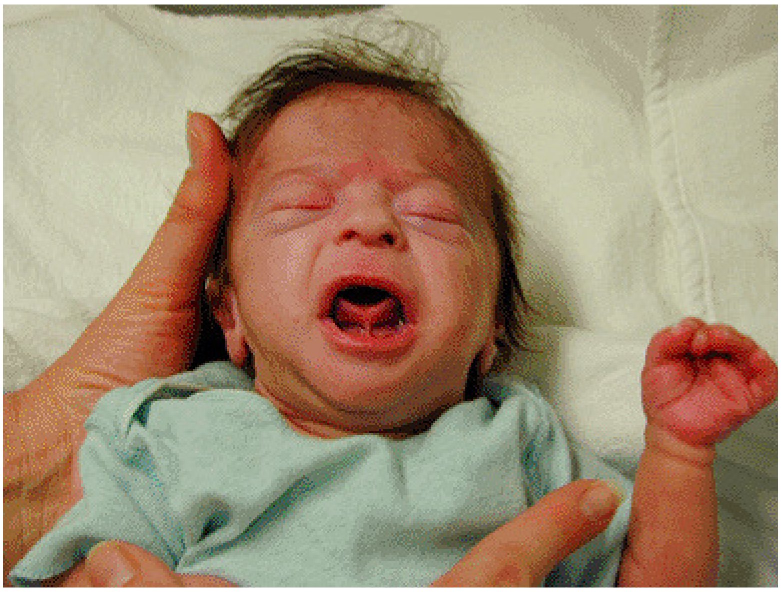

FIG. 54.1. Newborn with significant ankyloglossia. Note heart-shaped tongue, inability to raise tongue tip toward roof of mouth.

D. Indications

- In the neonate, presence of ankyloglossia, usually in a breastfeeding infant, causing one or more of the following (11,16,17,21):
  - Maternal nipple trauma, pain
  - Poor latch
  - Ineffective suckling; continuous suckling
  - Weight loss or poor infant weight gain
  - Early weaning

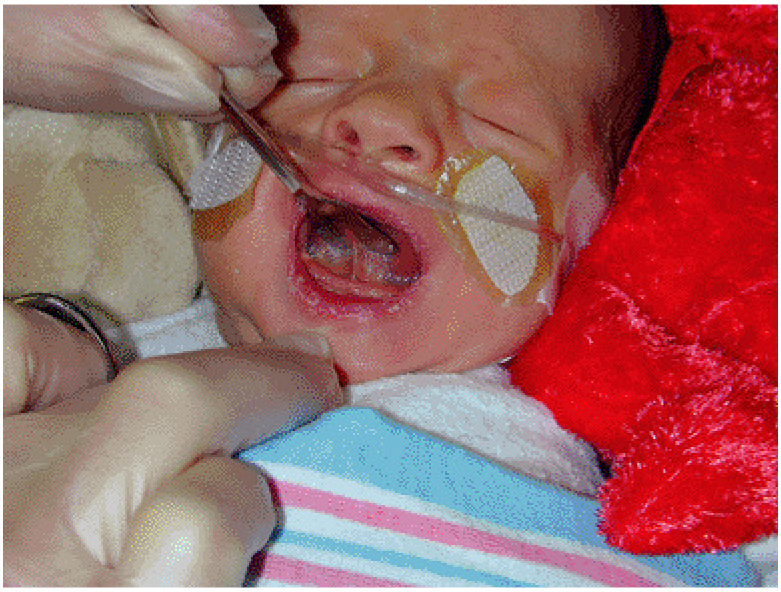

FIG. 54.2. Grooved retractor used to raise tongue and visualize the frenulum. Notice how thin and membranous the anterior edge is.

E. Contraindications

- Presence of genioglossus muscle or vascular tissue in the frenulum with no thin membranous tissue for incision

  Refer to appropriate surgeon for consideration for frenuloplasty.

F. Limitations

- If the difficulty with breastfeeding was not caused by the tongue tie, release of the tongue tie will not result in improvement.

  Even when tongue tie is the cause, attention must be paid to latch and suckling after release to ensure the best outcome.

G. Equipment

- Blanket or towel for swaddling
- Sterile iris scissors
- Sterile grooved retractor (optionalâ€”see below) (Fig. 54.2)
- Gloves
- Gauze pads
- Topical anesthetic gel for oral use (optionalâ€”see below)
- Cotton swab

H. Precautions (Fig. 54.2)

- Ensure, by careful examination of the frenulum, that there is no vascular or muscular tissue in the field of incision. Transillumination may be used to enhance visualization.
- Avoid submandibular duct orifices lateral to the frenulum.
- Avoid the thicker, more posterior part of the frenulum, which carries the blood supply.

I. Technique (2,3,7,12,15,20,21) (Figs. 54.2 and 54.3)

- Place the infant on a firm surface.
- Firmly swaddle the infant in a blanket or towel with the arms swaddled in at the sides.
- Have an assistant standing at the head of the infant to stabilize the shoulders with their fingers while steadying the head with their palms.
- Stand on right side of infant if right-handed.
- Visualize the frenulum by positioning light source to the left of the infant, allowing essentially transillumination of the frenulum.
- Place two gloved fingers of the left hand below the tongue, on either side of the midline, or position a grooved retractor, to push the tongue up toward the roof of the mouth, exposing the frenulum.
- Inspect the frenulum for any vascular or muscular structures.

  Frenotomy should be done only if the frenulum is thin, transparent, and with no other structures present.

- Utilization of local anesthesia (optional):
  - With no anesthesia, there is minimal, brief discomfort (6,11,12,15,20,22) because the frenulum is poorly innervated.

    Babies frequently squirm with positioning but usually do not cry during procedure.

  - Alternatively, topical anesthetic gel can be applied to the frenulum with a cotton swab.

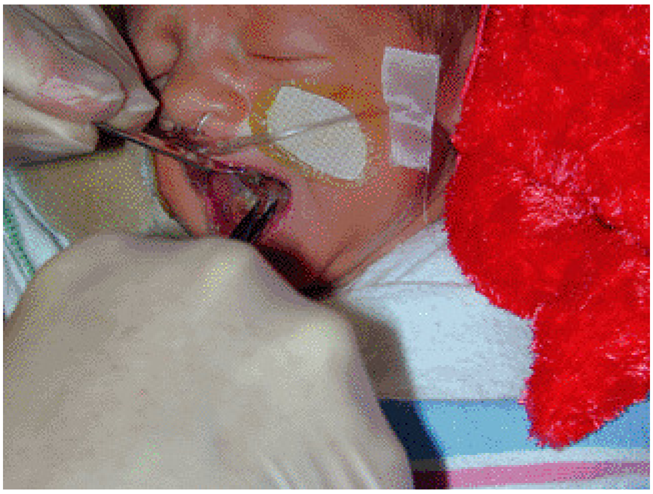

FIG. 54.3. Grooved retractor used to raise tongue. Iris scissors make incision.

- Divide the membranous frenulum with iris scissors (Fig. 54.3):
  - Begin at the free border, proceed posteriorly, closer to the tongue than to the floor of the mouth.
  - Occasionally, a single cut will free the tongue sufficiently.
  - Usually, 2 to 3 small, sequential cuts (1 to 3 mm) are required.

    Each subsequent cut allows improved retraction and visualization for the next cut.

  - Divide frenulum anterior to the vascular bundle until tongue is freed and can extend past lower alveolar ridge and lips (Fig. 54.4).

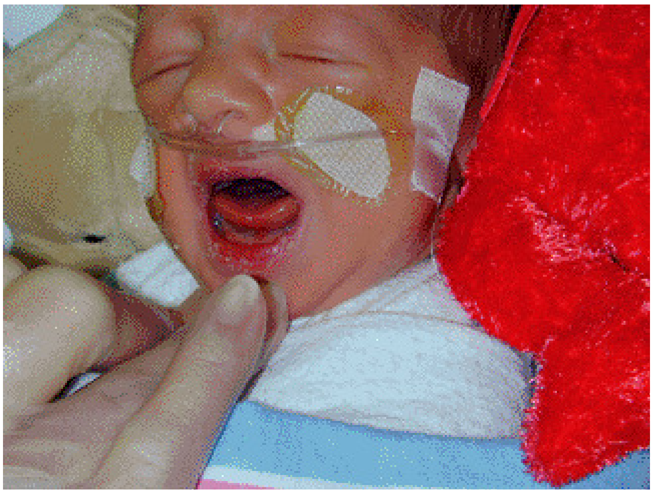

FIG. 54.4. After incision, minimal blood noted. Tongue now extends past lower alveolar ridge.

- Control any bleeding (usually minimal) with direct pressure applied with a sterile gauze pad.
- Inform mother that breastfeeding may resume immediately.

  Mothers frequently note an immediate and dramatic improvement in breastfeeding, with reduced discomfort, improved latch, stronger suckling, and absence of the clicking sounds frequently produced by the tongue-tied infant when attempting to breastfeed.

- Antibiotic therapy is not required.
- Postoperatively, a white fibrin clot may form.

  Reassure parents that this is not a sign of infection.

- Arrange follow-up in 1 to 2 weeks to check healing of the incision.

J. Complications (2,4,11,12,15,20,22)

- Extremely rare when performed by practitioner familiar and comfortable with the procedure
  - Excessive bleeding virtually never occurs unless deep lingual arteries and/or veins are severed.
  - Infection
  - Recurrent ankyloglossia due to excessive scarring
    - Generally less severe than original presentation
    - Often amenable to revision surgery
  - Glossoptosis (tongue swallowing) due to excessive tongue mobility

    Theoretical concern; has never been reported in modern literature

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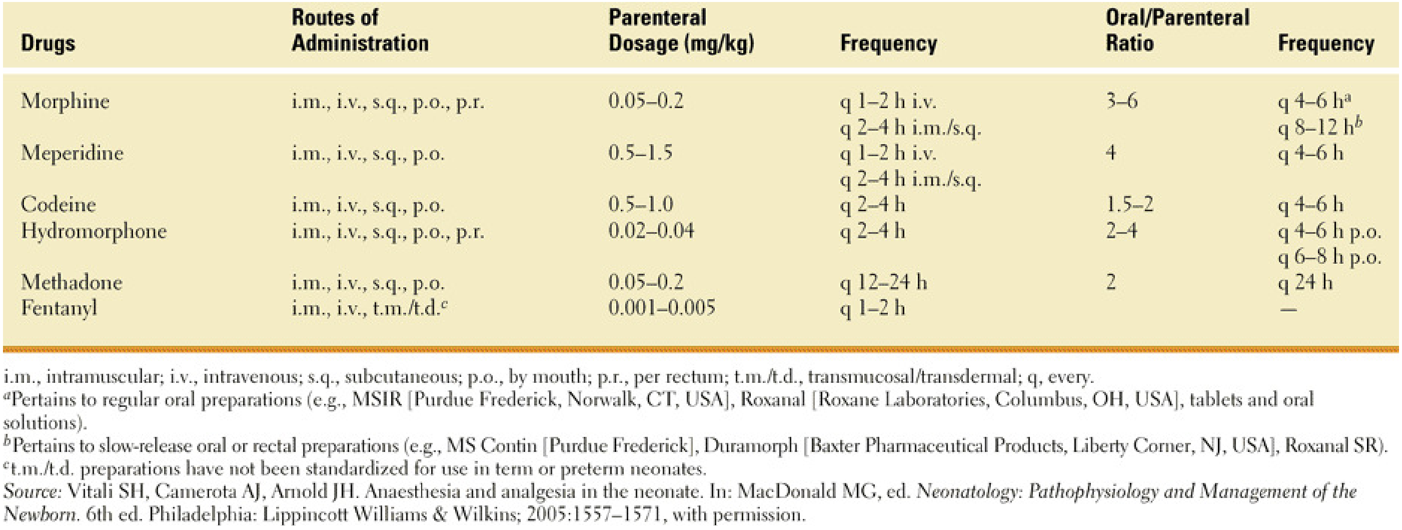
Appendices

Appendix A: Chapter 5

TABLE A.1 Recommended Dosages and Oral/Parenteral Ratios for Opioids



Drugs	Routes of Administration	Parenteral Dosage (mg/kg)	Frequency	Oral/Parenteral Ratio	Frequency
Morphine	i.m., i.v., s.q., p.o., p.r.	0.05–0.2	q 1–2 h i.v. q 2–4 h i.m./s.q.	3–6	q 4–6 h[a] q 8–12 h[b]
Meperidine	i.m., i.v., s.q., p.o.	0.5–1.5	q 1–2 h i.v. q 2–4 h i.m./s.q.	4	q 4–6 h
Codeine	i.m., i.v., s.q., p.o.	0.5–1.0	q 2–4 h	1.5–2	q 4–6 h
Hydromorphone	i.m., i.v., s.q., p.o., p.r.	0.02–0.04	q 2–4 h	2–4	q 4–6 h p.o. q 6–8 h p.o.
Methadone	i.m., i.v., s.q., p.o.	0.05–0.2	q 12–24 h	2	q 24 h
Fentanyl	i.m., i.v., t.m./t.d.[c]	0.001–0.005	q 1–2 h		—

i.m., intramuscular; i.v., intravenous; s.q., subcutaneous; p.o., by mouth; p.r., per rectum; t.m./t.d., transmucosal/transdermal; q, every.

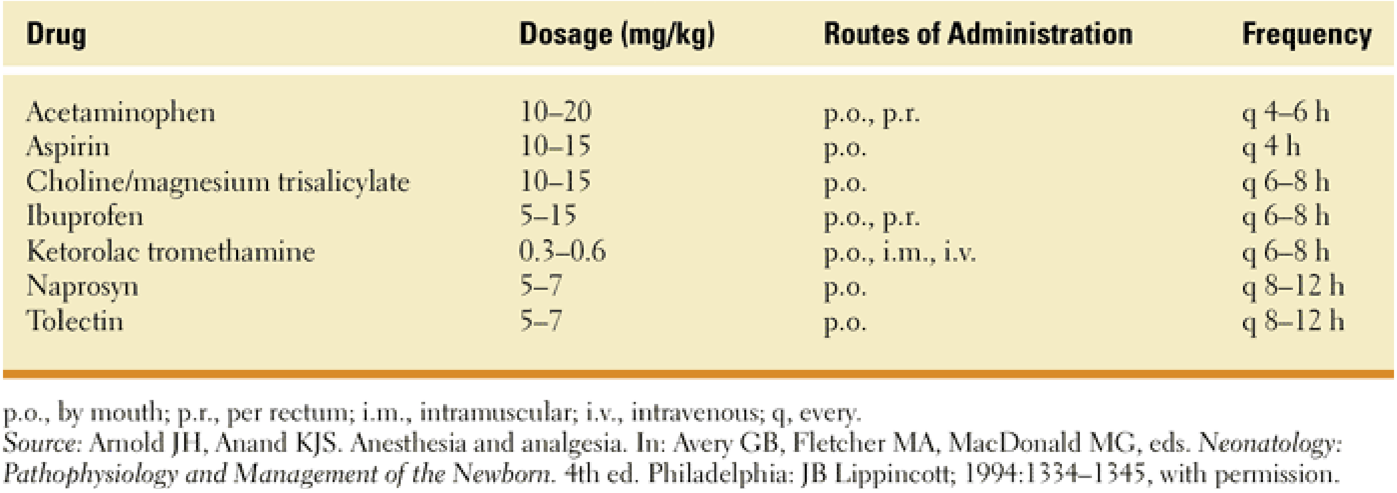
[a] Pertains to regular oral preparations (e.g., MSIR [Purdue Frederick, Norwalk, CT, USA], Roxanal [Roxane Laboratories, Columbus, OH, USA], tablets and oral solutions).

[b] Pertains to slow-release oral or rectal preparations (e.g., MS Contin [Purdue Frederick], Duramorph [Baxter Pharmaceutical Products, Liberty Corner, NJ, USA], Roxanal SR).

[c] t.m./t.d. preparations have not been standardized for use in term or preterm neonates.

Source: Vitali SH, Camerota AJ, Arnold JH. Anaesthesia and analgesia in the neonate. In: MacDonald MG, ed. *Neonatology: Pathophysiology and Management of the Newborn.* 6th ed. Philadelphia: Lippincott Williams & Wilkins; 2005:1557–1571, with permission.

TABLE A.2 Recommended Dosages for Nonsteroidal Anti-inflammatory Drugs



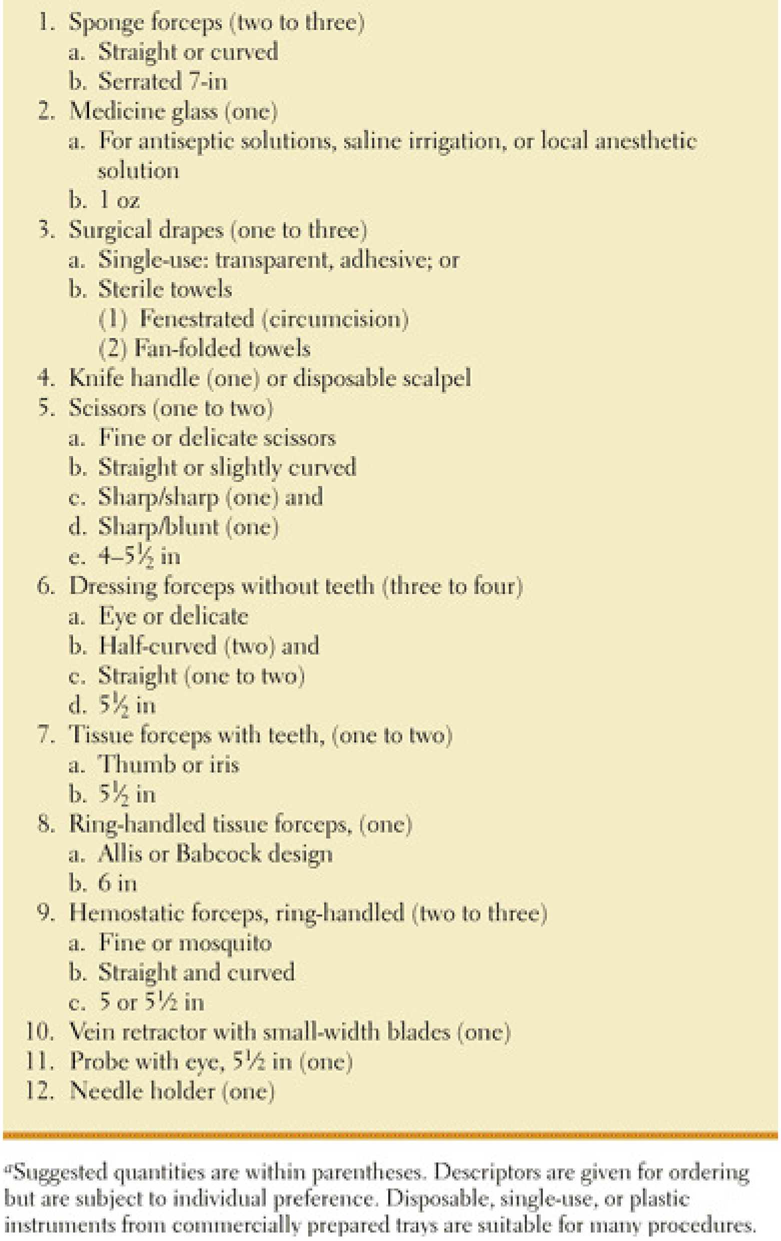
Drug	Dosage (mg/kg)	Routes of Administration	Frequency
Acetaminophen	10–20	p.o., p.r.	q 4–6 h
Aspirin	10–15	p.o.	q 4 h
Choline/magnesium trisalicylate	10–15	p.o.	q 6–8 h
Ibuprofen	5–15	p.o., p.r.	q 6–8 h
Ketorolac tromethamine	0.3–0.6	p.o., i.m., i.v.	q 6–8 h
Naprosyn	5–7	p.o.	q 8–12 h
Tolectin	5–7	p.o.	q 8–12 h

p.o., by mouth; p.r., per rectum; i.m., intramuscular; i.v., intravenous; q, every.

Source: Arnold JH, Anand KJS. Anesthesia and analgesia. In: Avery GB, Fletcher MA, MacDonald MG, eds. *Neonatology: Pathophysiology and Management of the Newborn.* 4th ed. Philadelphia: JB Lippincott; 1994:1334–1345, with permission.

Appendix B Chapter 31

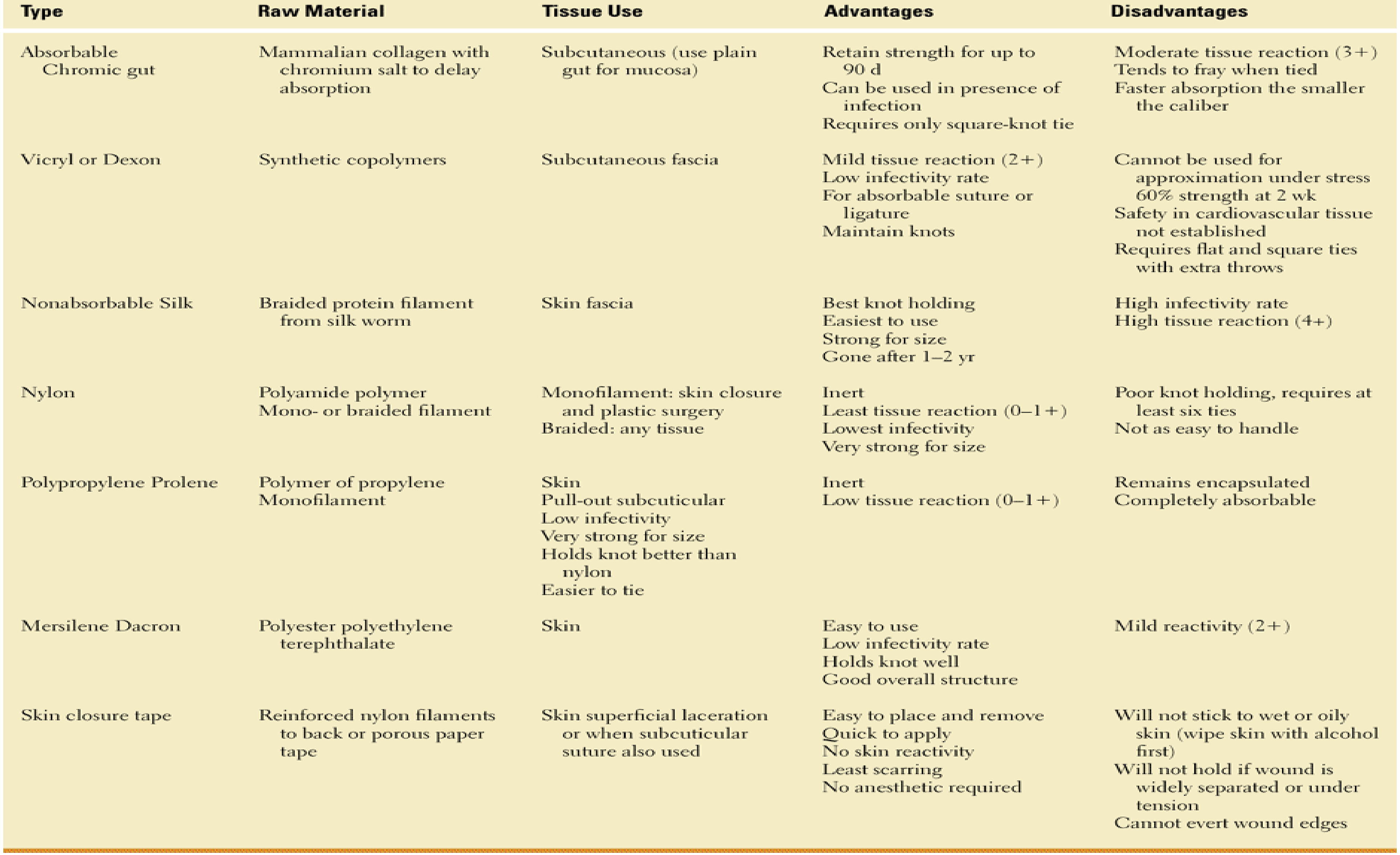
TABLE B.1 Basic, All-Purpose Instrument Tray[a]



1. Sponge forceps (two to three)
    a. Straight or curved
    b. Serrated 7-in
2. Medicine glass (one)
    a. For antiseptic solutions, saline irrigation, or local anesthetic solution
    b. 1 oz
3. Surgical drapes (one to three)
    a. Single-use: transparent, adhesive; or
    b. Sterile towels
        (1) Fenestrated (circumcision)
        (2) Fan-folded towels
4. Knife handle (one) or disposable scalpel
5. Scissors (one to two)
    a. Fine or delicate scissors
    b. Straight or slightly curved
    c. Sharp/sharp (one) and
    d. Sharp/blunt (one)
    e. 4–5½ in
6. Dressing forceps without teeth (three to four)
    a. Eye or delicate
    b. Half-curved (two) and
    c. Straight (one to two)
    d. 5½ in
7. Tissue forceps with teeth, (one to two)
    a. Thumb or iris
    b. 5½ in
8. Ring-handled tissue forceps, (one)
    a. Allis or Babcock design
    b. 6 in
9. Hemostatic forceps, ring-handled (two to three)
    a. Fine or mosquito
    b. Straight and curved
    c. 5 or 5½ in
10. Vein retractor with small-width blades (one)
11. Probe with eye, 5½ in (one)
12. Needle holder (one)

[a] Suggested quantities are within parentheses. Descriptors are given for ordering but are subject to individual preference. Disposable, single-use, or plastic instruments from commercially prepared trays are suitable for many procedures.

TABLE B.2 Selected Sutures Appropriate for Common Neonatal Procedure:

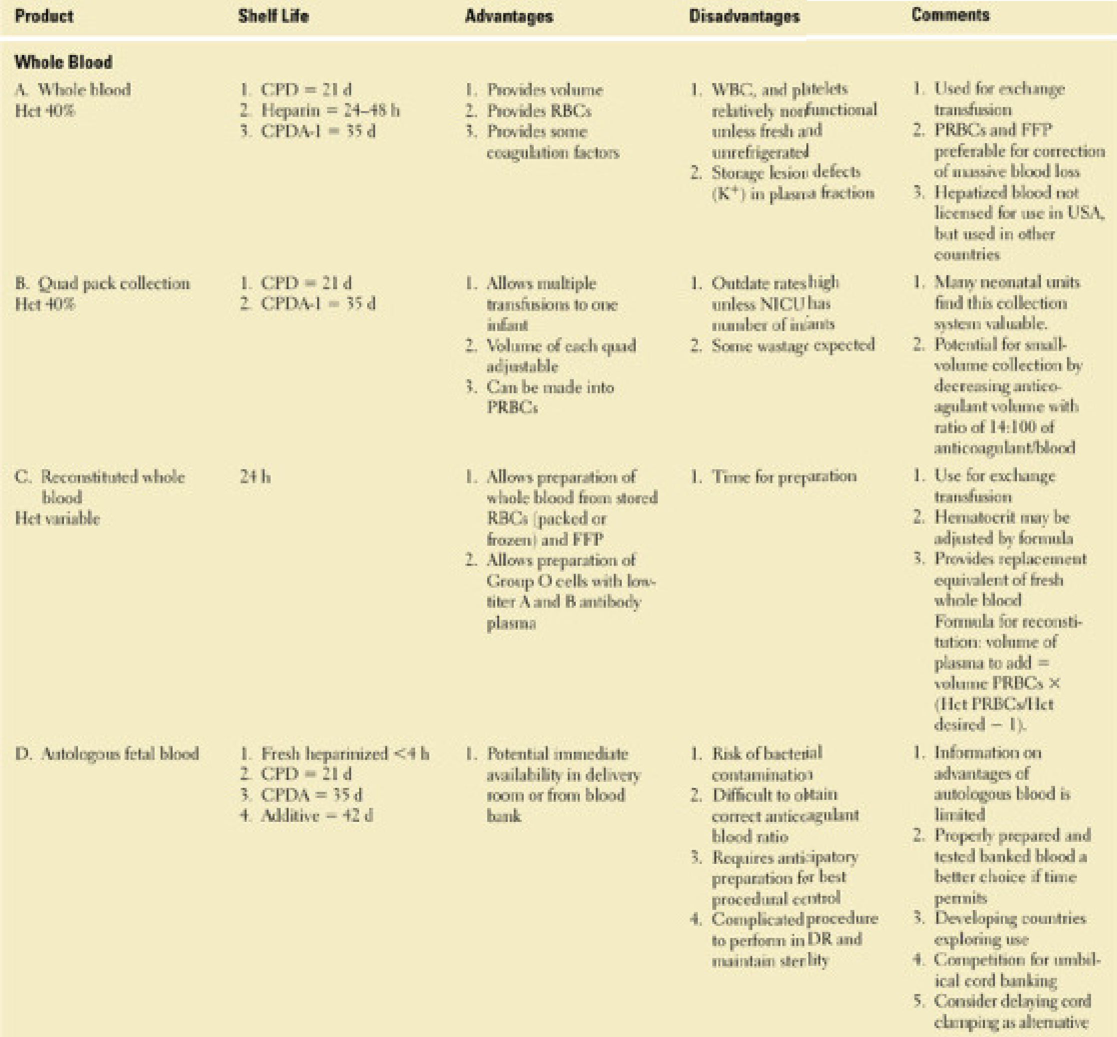


Type	Raw Material	Tissue Use	Advantages	Disadvantages
Absorbable Chromic gut	Mammalian collagen with chromium salt to delay absorption	Subcutaneous (use plain gut for mucosa)	Retain strength for up to 90 d Can be used in presence of infection Requires only square-knot tie	Moderate tissue reaction (3+) Tends to fray when tied Faster absorption the smaller the caliber
Vicryl or Dexon	Synthetic copolymers	Subcutaneous fascia	Mild tissue reaction (2+) Low infectivity rate For absorbable suture or ligature Maintain knots	Cannot be used for approximation under stress 60% strength at 2 wk Safety in cardiovascular tissue not established Requires flat and square ties with extra throws
Nonabsorbable Silk	Braided protein filament from silk worm	Skin fascia	Best knot holding Easiest to use Strong for size Gone after 1–2 yr	High infectivity rate High tissue reaction (4+)
Nylon	Polyamide polymer Mono- or braided filament	Monofilament: skin closure and plastic surgery Braided: any tissue	Inert Least tissue reaction (0–1+) Lowest infectivity Very strong for size	Poor knot holding, requires at least six ties Not as easy to handle
Polypropylene Prolene	Polymer of propylene Monofilament	Skin Pull-out subcuticular Low infectivity Very strong for size Holds knot better than nylon Easier to tie	Inert Low tissue reaction (0–1+)	Remains encapsulated Completely absorbable
Mersilene Dacron	Polyester polyethylene terephthalate	Skin	Easy to use Low infectivity rate Holds knot well Good overall structure	Mild reactivity (2+)
Skin closure tape	Reinforced nylon filaments to back or porous paper tape	Skin superficial laceration or when subcuticular suture also used	Easy to place and remove Quick to apply No skin reactivity Least scarring No anesthetic required	Will not stick to wet or oily skin (wipe skin with alcohol first) Will not hold if wound is widely separated or under tension Cannot evert wound edges

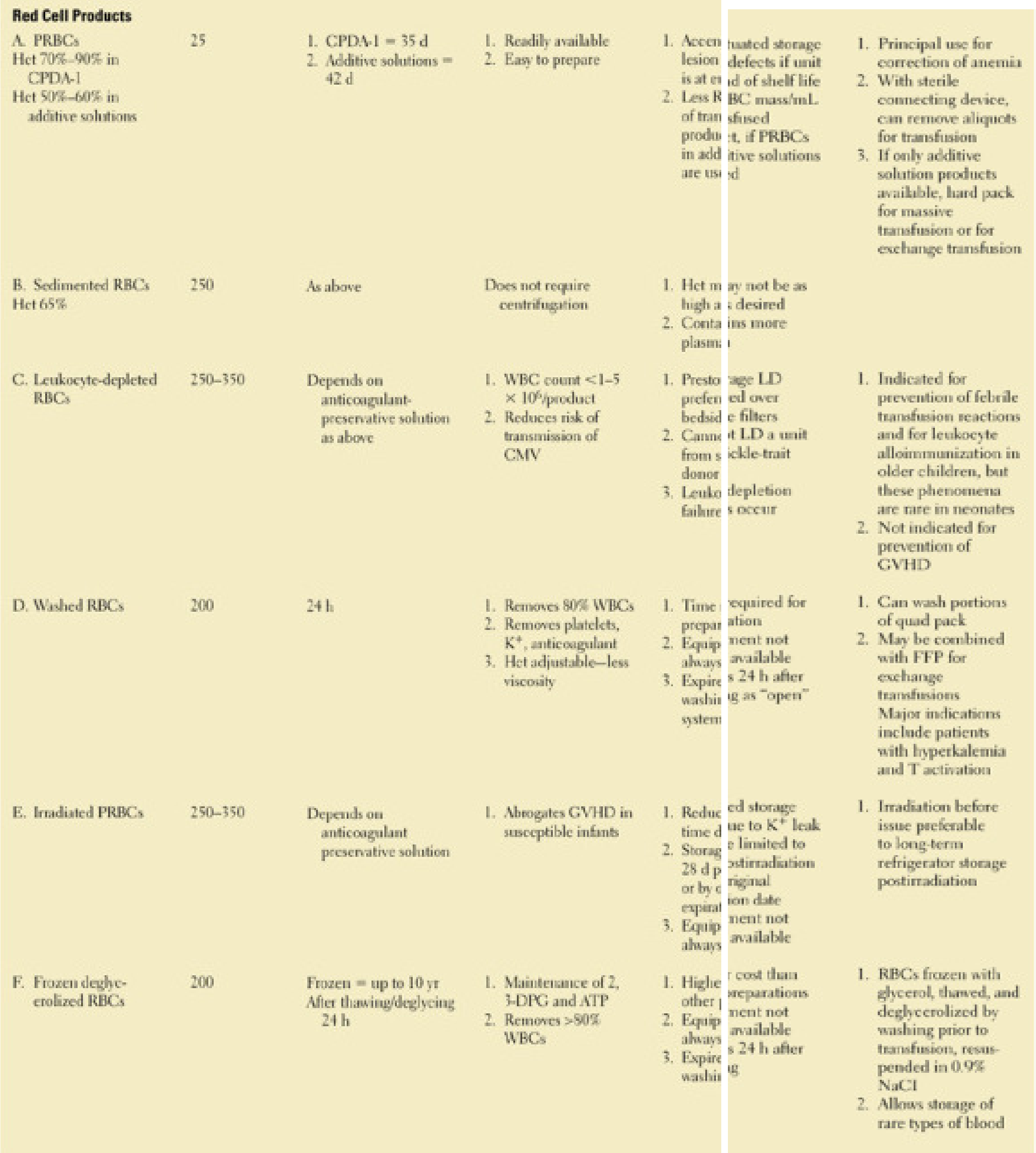
Appendix C: Chapter 41.

TABLE C.1 Blood Products

Shelf Life Advantages Disadvantages Comments

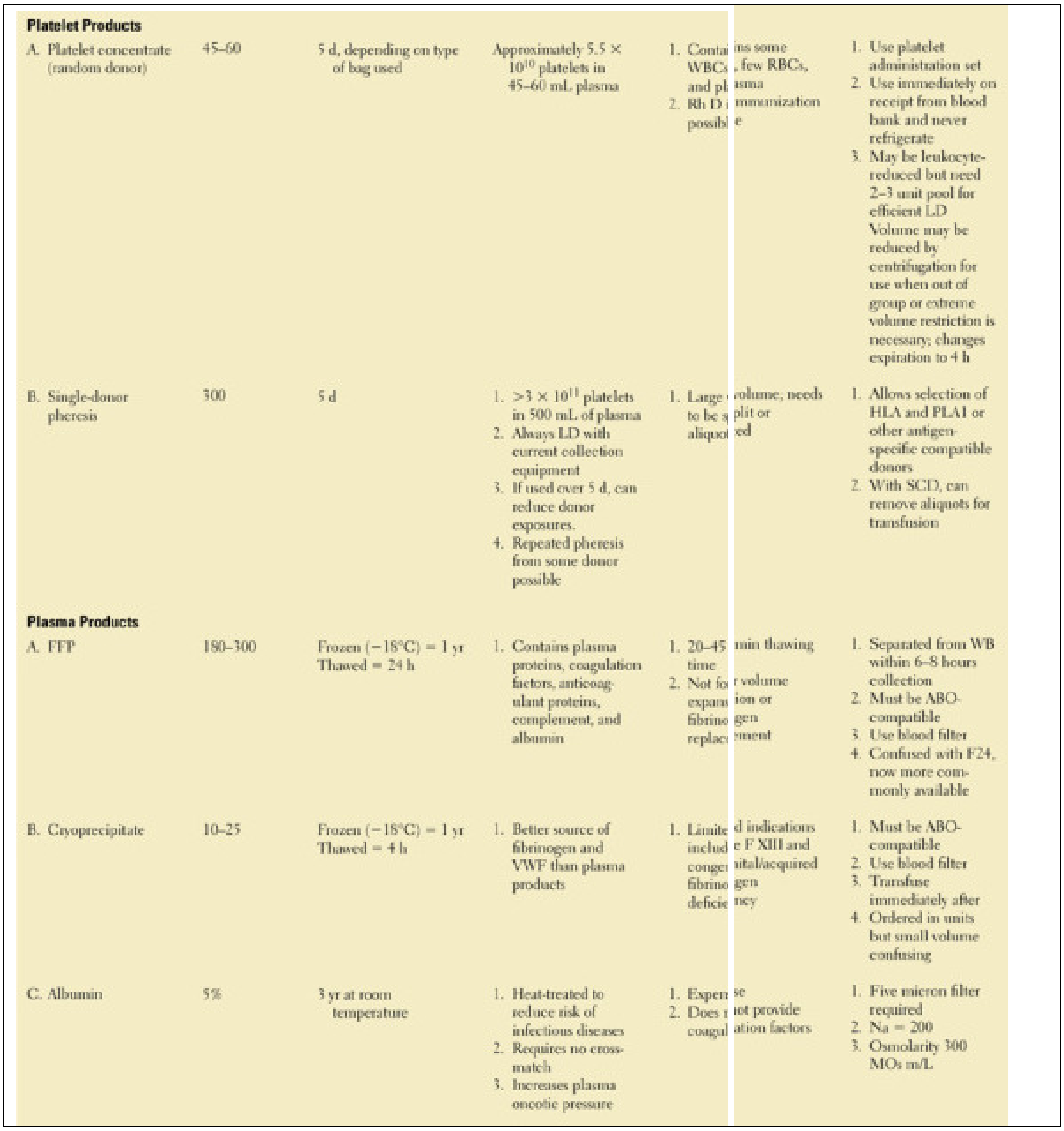


Product	Shelf Life	Advantages	Disadvantages	Comments
Whole Blood				
A. Whole blood Hct 40%	1. CPD = 21 d 2. Heparin = 24–48 h 3. CPDA-1 = 35 d	1. Provides volume 2. Provides RBCs 3. Provides some coagulation factors	1. WBC, and platelets relatively nonfunctional unless fresh and unrefrigerated 2. Storage lesion defects (K^+) in plasma fraction	1. Used for exchange transfusion 2. PRBCs and FFP preferable for correction of massive blood loss 3. Hepatized blood not licensed for use in USA, but used in other countries
B. Quad pack collection Hct 40%	1. CPD = 21 d 2. CPDA-1 = 35 d	1. Allows multiple transfusions to one infant 2. Volume of each quad adjustable 3. Can be made into PRBCs	1. Outdate rates high unless NICU has number of infants 2. Some wastage expected	1. Many neonatal units find this collection system valuable. 2. Potential for small-volume collection by decreasing anticoagulant volume with ratio of 14:100 of anticoagulant/blood
C. Reconstituted whole blood Hct variable	24 h	1. Allows preparation of whole blood from stored RBCs (packed or frozen) and FFP 2. Allows preparation of Group O cells with low-titer A and B antibody plasma	1. Time for preparation	1. Use for exchange transfusion 2. Hematocrit may be adjusted by formula 3. Provides replacement equivalent of fresh whole blood Formula for reconstitution: volume of plasma to add = volume PRBCs × (Hct PRBCs/Hct desired − 1).
D. Autologous fetal blood	1. Fresh heparinized <4 h 2. CPD = 21 d 3. CPDA = 35 d 4. Additive = 42 d	1. Potential immediate availability in delivery room or from blood bank	1. Risk of bacterial contamination 2. Difficult to obtain correct anticoagulant blood ratio 3. Requires anticipatory preparation for best procedural control 4. Complicated procedure to perform in DR and maintain sterility	1. Information on advantages of autologous blood is limited 2. Properly prepared and tested banked blood a better choice if time permits 3. Developing countries exploring use 4. Competition for umbilical cord banking 5. Consider delaying cord clamping as alternative

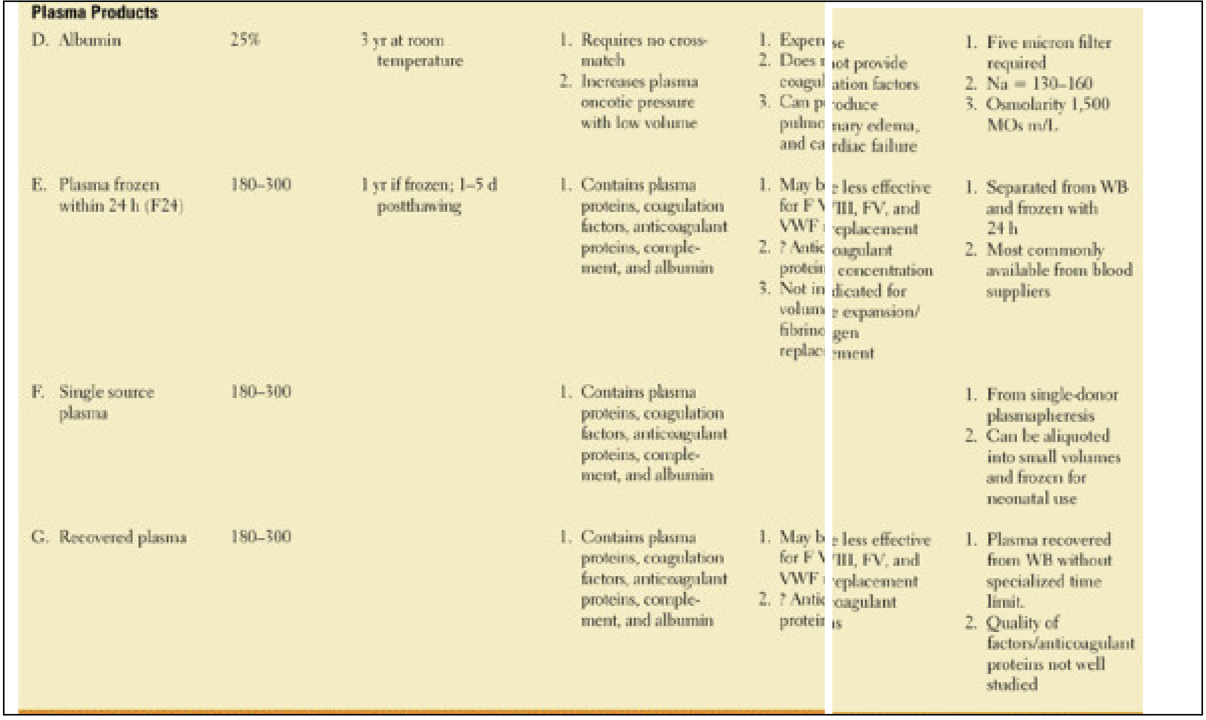


Product	**Shelf Life**		**Advantages**	**Disadvantages**	**Comments**
Red Cell Products					
A. PRBCs Hct 70%–90% in CPDA-1 Hct 50%–60% in additive solutions	25	1. CPDA-1 = 35 d 2. Additive solutions = 42 d	1. Readily available 2. Easy to prepare	1. Accen tuated storage lesion defects if unit is at e d of shelf life 2. Less R BC mass/mL of tran sfused produ t, if PRBCs in add itive solutions are us d	1. Principal use for correction of anemia 2. With sterile connecting device, can remove aliquots for transfusion 3. If only additive solution products available, hard pack for massive transfusion or for exchange transfusion
B. Sedimented RBCs Hct 65%	250	As above	Does not require centrifugation	1. Hct m ay not be as high a desired 2. Conta ins more plasm	
C. Leukocyte-depleted RBCs	250–350	Depends on anticoagulant-preservative solution as above	1. WBC count <1–5 × 10⁶/product 2. Reduces risk of transmission of CMV	1. Presto age LD prefer ed over bedsid e filters 2. Cann t LD a unit from s ickle-trait donor 3. Leuko depletion failure s occur	1. Indicated for prevention of febrile transfusion reactions and for leukocyte alloimmunization in older children, but these phenomena are rare in neonates 2. Not indicated for prevention of GVHD
D. Washed RBCs	200	24 h	1. Removes 80% WBCs 2. Removes platelets, K⁺, anticoagulant 3. Hct adjustable—less viscosity	1. Time equired for prepar ation 2. Equip ment not always available 3. Expire s 24 h after washi g as "open" system	1. Can wash portions of quad pack 2. May be combined with FFP for exchange transfusions Major indications include patients with hyperkalemia and T activation
E. Irradiated PRBCs	250–350	Depends on anticoagulant preservative solution	1. Abrogates GVHD in susceptible infants	1. Reduc ed storage time d ue to K⁺ leak 2. Storag e limited to 28 d p ostirradiation or by riginal expirat ion date 3. Equip ment not always available	1. Irradiation before issue preferable to long-term refrigerator storage postirradiation
F. Frozen deglycerolized RBCs	200	Frozen = up to 10 yr After thawing/deglycing 24 h	1. Maintenance of 2, 3-DPG and ATP 2. Removes >80% WBCs	1. Highe r cost than other preparations 2. Equip ment not always available 3. Expire s 24 h after washi g	1. RBCs frozen with glycerol, thawed, and deglycerolized by washing prior to transfusion, resuspended in 0.9% NaCl 2. Allows storage of rare types of blood

Product **Shelf Life** **Advantages** **Disadvantages** **Comments**



Platelet Products					
A. Platelet concentrate (random donor)	45–60	5 d, depending on type of bag used	Approximately 5.5 × 10^{10} platelets in 45–60 mL plasma	1. Contains some WBCs, few RBCs, and plasma 2. Rh D immunization possible	1. Use platelet administration set 2. Use immediately on receipt from blood bank and never refrigerate 3. May be leukocyte-reduced but need 2–3 unit pool for efficient LD Volume may be reduced by centrifugation for use when out of group or extreme volume restriction is necessary; changes expiration to 4 h
B. Single-donor pheresis	300	5 d	1. >3 × 10^{11} platelets in 300 mL of plasma 2. Always LD with current collection equipment 3. If used over 5 d, can reduce donor exposures. 4. Repeated pheresis from some donor possible	1. Large volume; needs to be split or aliquoted	1. Allows selection of HLA and PLA1 or other antigen-specific compatible donors 2. With SCD, can remove aliquots for transfusion
Plasma Products					
A. FFP	180–300	Frozen (−18°C) = 1 yr Thawed = 24 h	1. Contains plasma proteins, coagulation factors, anticoagulant proteins, complement, and albumin	1. 20–45 min thawing time 2. Not for volume expansion or fibrinogen replacement	1. Separated from WB within 6–8 hours collection 2. Must be ABO-compatible 3. Use blood filter 4. Confused with F24, now more commonly available
B. Cryoprecipitate	10–25	Frozen (−18°C) = 1 yr Thawed = 4 h	1. Better source of fibrinogen and VWF than plasma products	1. Limited indications include F XIII and congenital/acquired fibrinogen deficiency	1. Must be ABO-compatible 2. Use blood filter 3. Transfuse immediately after 4. Ordered in units but small volume confusing
C. Albumin	5%	3 yr at room temperature	1. Heat-treated to reduce risk of infectious diseases 2. Requires no cross-match 3. Increases plasma oncotic pressure	1. Expense 2. Does not provide coagulation factors	1. Five micron filter required 2. Na = 200 3. Osmolarity 300 MOs m/L



Product	Shelf Life		Advantages	Disadvantages	Comments
Plasma Products					
D. Albumin	25%	3 yr at room temperature	1. Requires no cross-match 2. Increases plasma oncotic pressure with low volume	1. Expen se 2. Does r ot provide coagul ation factors 3. Can pr oduce pulmo nary edema, and ca rdiac failure	1. Five micron filter required 2. Na = 130–160 3. Osmolarity 1,500 MOs m/L.
E. Plasma frozen within 24 h (F24)	180–300	1 yr if frozen; 1–5 d postthawing	1. Contains plasma proteins, coagulation factors, anticoagulant proteins, complement, and albumin	1. May b e less effective for F VIII, FV, and VWF replacement 2. ? Antic oagulant protein concentration 3. Not in dicated for volum e expansion/ fibrino gen replac ement	1. Separated from WB and frozen with 24 h 2. Most commonly available from blood suppliers
F. Single source plasma	180–300		1. Contains plasma proteins, coagulation factors, anticoagulant proteins, complement, and albumin		1. From single-donor plasmapheresis 2. Can be aliquoted into small volumes and frozen for neonatal use
G. Recovered plasma	180–300		1. Contains plasma proteins, coagulation factors, anticoagulant proteins, complement, and albumin	1. May b e less effective for F VIII, FV, and VWF replacement 2. ? Antic oagulant protei ns	1. Plasma recovered from WB without specialized time limit. 2. Quality of factors/anticoagulant proteins not well studied

Appendix D: Chapter 34.
Techniques for Endotracheal Intubation Specific to Unique Patient Needs

Elective Change of Orotracheal Tube in Intubated Patient

This procedure allows continued ventilation through a pre-established airway whenever it is necessary to change an endotracheal (ET) tube or to place a nasotracheal tube. By maintaining the original airway as long as possible during the change, there is less need for haste and less stress to the patient. An obvious prerequisite is that the original ET tube be patent and correctly positioned in the trachea.

Rapid Replacement Method

- Prepare equipment and patient as for initial orotracheal intubation.
- Release tube fixation device without displacing tube.
- Have assistant hold first ET tube in place at far left of the infant's mouth while continuing to ventilate infant.
- Visualize glottis with laryngoscope.
- Pass second orotracheal tube down far right of the mouth until it aligns with glottic opening.
- When new tube is positioned for direct insertion, have assistant withdraw first tube carefully.
- Advance new tube into position.
- Verify position and secure tube as previously described.

Alternative Method: Insertion over a Feeding Tube

Because of the narrow diameter of ET tubes in small infants, feeding tubes narrow enough to fit inside the ET lumen are often too flexible to stay within the trachea as the tubes are being changed. Be prepared to intubate directly should the feeding tube dislodge.

- Prepare equipment and patient as for initial orotracheal intubation.
- Release tube fixation device without displacing tube.
- Select the largest feeding tube that will easily go through the current and new endotracheal tubes. Remove the flared end of feeding tube and the adaptor on the new tube.
- Remove adaptor of currently in-place ET tube.
- Quickly insert the feeding tube through the lumen to a depth not greater than the ET tube.
- While holding feeding tube in place, pull ET tube out of trachea and off feeding tube.
- Slide new ET tube over feeding tube into trachea.
- Replace tube adaptor.
- Verify position and secure tube as previously described.

Selective Left Endobronchial Intubation

The angles of the bronchi are such that more often than not a tube will seek the right mainstem bronchus. The exceptions will be conditions that push the left side down (left upper-lobe emphysema) or that pull the right side up (marked upper-lobe atelectasis or hypoplasia). Normally, successful right mainstem intubation simply requires a longer tube. Selective intubation of the left bronchus is a more difficult and dangerous procedure; therefore, following all precautions is especially important.

Place the ET tube under guidance by direct bronchoscopy or under fluoroscopy when these procedures are available without compromise to infants (1,2).

The following procedure is a simple, indirect method based on a modification that tends to make the ET tube bend toward the left when it meets resistance at the carina (3).

- Cut an elliptical hole through half the diameter of ET tube 1 cm in length and 0.5 cm above the tip of the oblique distal end.
- Perform an orotracheal intubation as above, keeping the cut hole directed toward the left lung.
- Turn infant's head toward the right (4).
- While auscultating the lung fields, advance the tube to 0.5 to 1 cm below the calculated depth of the carina or until differential breath sounds are heard.
- If breath sounds diminish on the left, withdraw the ET tube until they return.
- Take a chest radiograph to confirm left bronchial position.
- Fix tube securely.
- Reassess position frequently, as tube may dislodge from one mainstem into the other.
- Follow patient closely for particular complications of
    - Air leak of ventilated area
    - Stasis pneumonia of nonventilated area
    - Dislodgement from left mainstem bronchus
    - Ventilatory insufficiency due to significant disease in the only lung being ventilated

Nonvisualized Oral Intubation

This technique has a higher risk of complications and is less often successful than when direct visualization is used. Reserve the blind oral intubation for true emergencies in small infants when there is equipment failure (e.g., laryngoscope light) and when ventilation by mask is contraindicated (e.g., thick meconium).

- Stand at infant's feet.
- Carefully slide first two fingers of gloved, left hand into back of oropharynx at the base of tongue, until reaching vallecula and epiglottis. Keep fingers in the center of the tongue.
- Using index finger, pull epiglottis forward.
- Keep infant's head in midline.
- With right hand, guide ET tube, without stylet, along left middle finger, which is held just above index finger.
- Advance tube carefully just beyond fingertips.
- Avoid pushing against any obstruction.
- If available, have assistant press gently on trachea in suprasternal notch and report when tube passes under finger.
- Verify position, and fix tube as previously described.

Blind Nasotracheal Intubation (5)

Blind nasotracheal intubation is often used in adults. Because a stiff tube is needed, the chance of perforation in infants is greater if a stylet is used. Although an intubation under direct visualization is preferred, the presence of severe microagnathia or oral masses makes this approach valuable. It is critical not to push against any resistance.

- Keep infant supine with neck flexed and shoulders supported by a small roll.
- Shape a stylet so the tip of the endotracheal tube will curve anteriorly at 90 degrees. Be certain the tip of the stylet stays above the end of the ET tube. Alternately, freeze an ET tube in this configuration and remove stylet just prior to insertion.
- Maintaining the curve in the tube anterior, insert the tube carefully through the nostril until its tip is in the oropharynx.
- Pull the jaw forward into a sniff position with the head midline and put slight external pressure over the cricoid cartilage.
- Advance the tube to a suitable depth unless there is any resistance.
- Remove stylet and verify presence of exhaled humidity and equal breath sounds.

Intubation in Severe Cleft Defects

There are several possible modifications for ET tubes that are useful for fixation or elective intubation when there is a large cleft palate. For emergency intubations, the following modification using a standard tongue blade is usually immediately available (6). For techniques or difficult intubation alternatives, see above (7).

- Open infant's mouth and lay sterile tongue blade flat across maxilla, with ends extending from corners mouth. Have assistant hold in place.
- Follow steps for routine intubation, using tongue blade for support of laryngoscope as necessary.
- After intubation, fix tube to padded tongue blade.
- Recognize that tongue thrust on tube in absence of a normal palate may lead to extubation even without visible external lengthening of tube.

Emergency Retrograde Intubation (8)

When facial anomalies preclude other routes, retrograde intubation using a modified Seldinger technique is possible. Because the cartilaginous support of the trachea is so poor, needle puncture is far more difficult in neonates.

Equipment

- Venous cannula with stylet, 14 or 16 gauge
- Feeding catheter. Verify that the catheter will pass through the lumen of the angiocath.
    - A 14-gauge cannula will admit a 5-French (Fr) feeding tube.
    - A 16-gauge cannula will admit a 3.5-Fr feeding tube.
- Hemostat
- Endotracheal tube

Technique

- Sedate infant if possible.
- Clean skin over cricothyroid area
- At the level of the cricothyroid, puncture skin with cannula and stylet. Angle cannula at 45 degrees from the skin and directed toward the head.
- Insert into lumen or trachea only until there is a give in resistance or air returns.
- Remove the stylet.
- Thread feeding tube through the lumen of the cannula until it can be retrieved from the nose or oropharynx.
- Bring cephalic end of feeding tube out of the nose or mouth, leaving other end well outside skin insertion.
- While feeding tube is in place, remove the cannula from the tracheal insertion site.
- Clamp the feeding tube at its tracheal insertion so it will not be pulled into the trachea farther than desired.
- At the upper end, slip the ET tube over the feeding tube and along its course until it has passed the proper distance into the trachea. Stabilize the ET tube.
- Cut the feeding tube at its tracheal insertion.
- While keeping the ET tube in place, pull the feeding tube through the ET tube.
- Secure ET tube after verifying correct intratracheal position.

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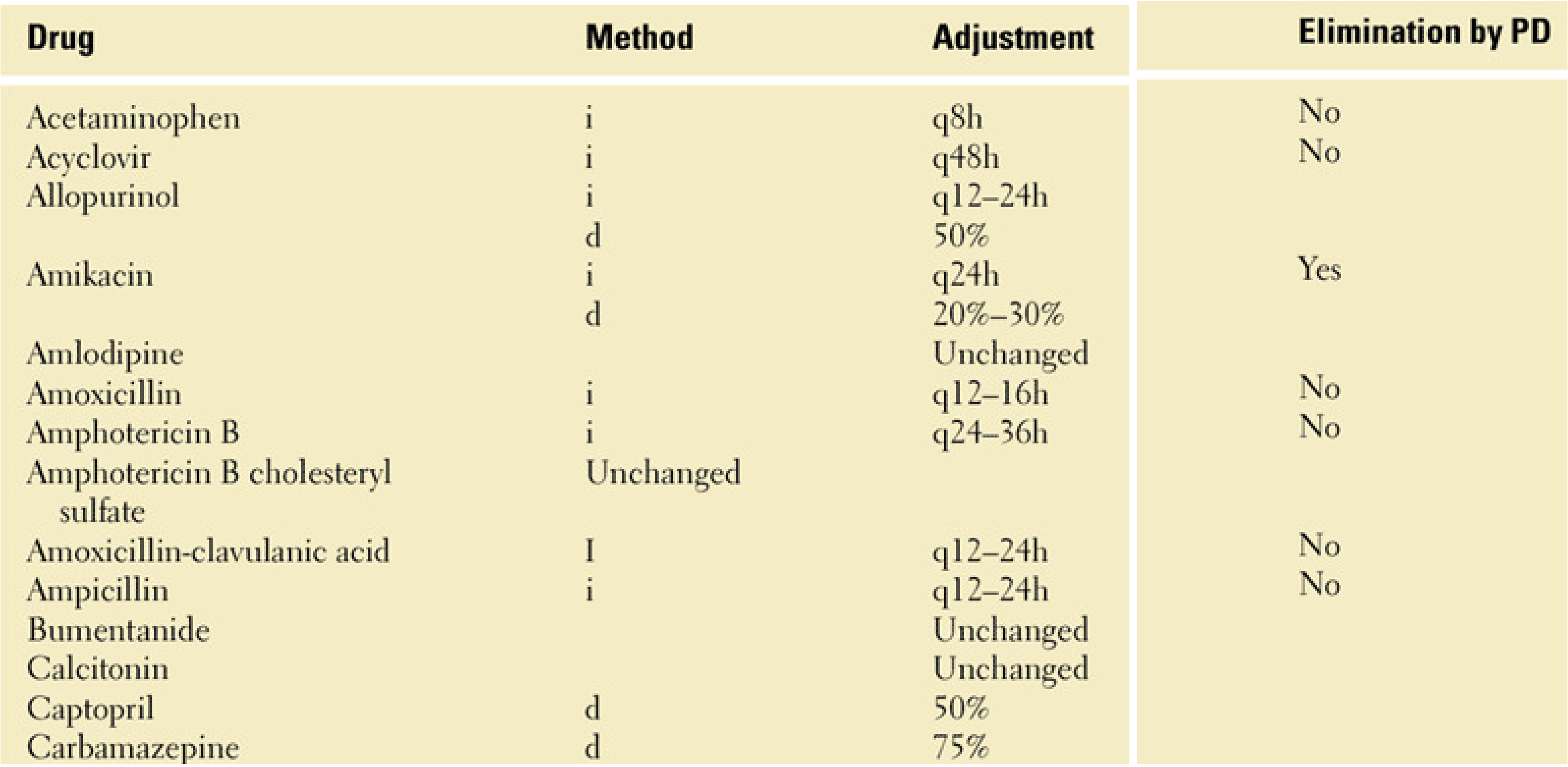
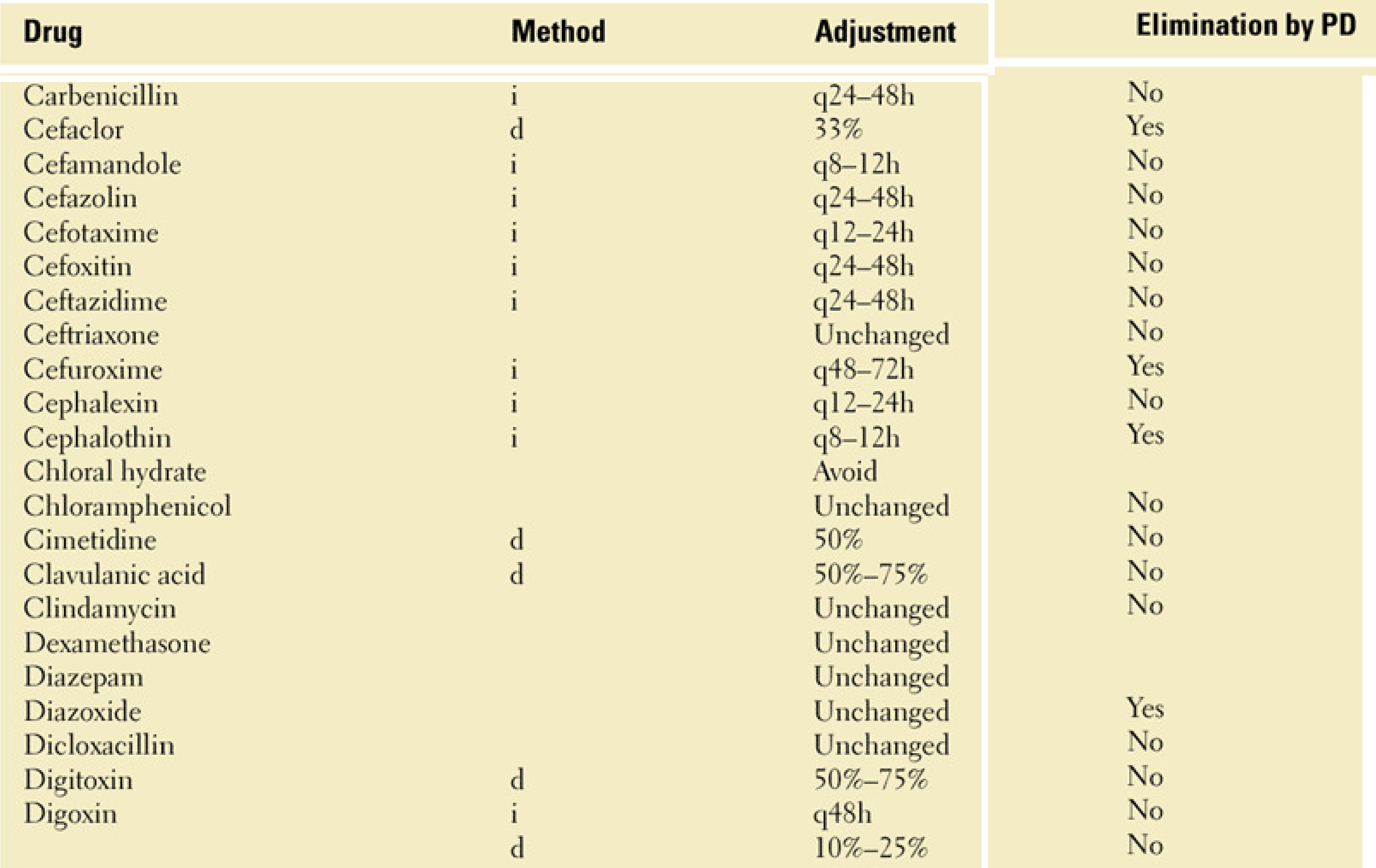
Appendix E: Chapter 50

TABLE E.1 Drugs Requiring Adjustment in Severe Renal Failure



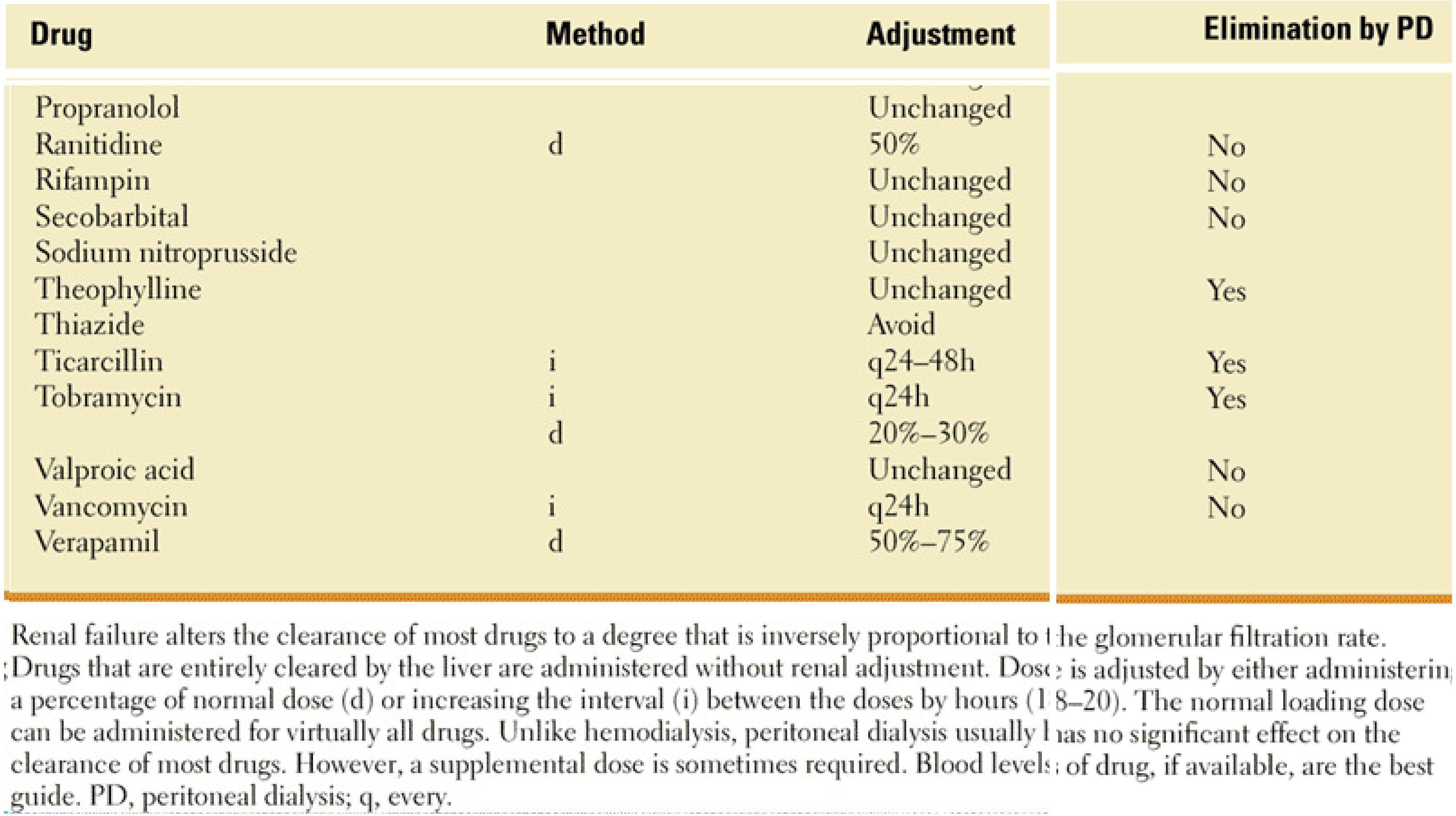
Drug	Method	Adjustment	Elimination by PD
Acetaminophen	i	q8h	No
Acyclovir	i	q48h	No
Allopurinol	i	q12–24h	
	d	50%	
Amikacin	i	q24h	Yes
	d	20%–30%	
Amlodipine		Unchanged	
Amoxicillin	i	q12–16h	No
Amphotericin B	i	q24–36h	No
Amphotericin B cholesteryl sulfate	Unchanged		
Amoxicillin-clavulanic acid	I	q12–24h	No
Ampicillin	i	q12–24h	No
Bumentanide		Unchanged	
Calcitonin		Unchanged	
Captopril	d	50%	
Carbamazepine	d	75%	



Drug	Method	Adjustment	Elimination by PD
Carbenicillin	i	q24–48h	No
Cefaclor	d	33%	Yes
Cefamandole	i	q8–12h	No
Cefazolin	i	q24–48h	No
Cefotaxime	i	q12–24h	No
Cefoxitin	i	q24–48h	No
Ceftazidime	i	q24–48h	No
Ceftriaxone		Unchanged	No
Cefuroxime	i	q48–72h	Yes
Cephalexin	i	q12–24h	No
Cephalothin	i	q8–12h	Yes
Chloral hydrate		Avoid	
Chloramphenicol		Unchanged	No
Cimetidine	d	50%	No
Clavulanic acid	d	50%–75%	No
Clindamycin		Unchanged	No
Dexamethasone		Unchanged	
Diazepam		Unchanged	
Diazoxide		Unchanged	Yes
Dicloxacillin		Unchanged	No
Digitoxin	d	50%–75%	No
Digoxin	i	q48h	No
	d	10%–25%	No

Drug	Method	Adjustment	Elimination by PD
Diphenhydramine	i	q9–12h	
Enoxaparin		Not approved	
Erythromycin		Unchanged	No
Ethambutol	i	q48h	Yes
Fentanyl		30%–50%	
Flucytosine	i	q24–48h	Yes
	d	20%–30%	
Fluconazole	d	25%	Yes
Furosemide		Unchanged	
Gentamicin	i	q24–48h	Yes
	d	20%–30%	
Heparin		Unchanged	
Hydrocortisone		Unchanged	
Hydralazine	i	q8–16h	No
Indomethacin		Unchanged	
Insulin (reg)	d	25%–50%	
Isoniazid		Unchanged	Yes
Kanamycin	i	q24h	Yes
	d	23%–30%	
Ketoconazole		Unchanged	No
Labetalol		Unchanged	
Lidocaine		Unchanged	

Drug	Method	Adjustment	Elimination by PD
Lorazepam	d	50%	
Meperidine	d	50%	No
Metoprolol		Unchanged	
Metronidazole	i	q12–24h	No
Morphine		To avoid	
Nafcillin		Unchanged	
Naloxone		Unchanged	No
Nicardipine	d, i	Titrate	?
Oxacillin		Unchanged	
Penicillin G	i	q12–16h	No
	d	25%–50%	
Pentobarbital		Unchanged	
Phenobarbital	i	12–16h	Yes
Phenytoin		Unchanged	
Piperacillin	i	q24h	No
Prednisone		Unchanged	
Propranolol		Unchanged	



Drug	Method	Adjustment	Elimination by PD
Propranolol		Unchanged	
Ranitidine	d	50%	No
Rifampin		Unchanged	No
Secobarbital		Unchanged	No
Sodium nitroprusside		Unchanged	
Theophylline		Unchanged	Yes
Thiazide		Avoid	
Ticarcillin	i	q24–48h	Yes
Tobramycin	i	q24h	Yes
	d	20%–30%	
Valproic acid		Unchanged	No
Vancomycin	i	q24h	No
Verapamil	d	50%–75%	

Renal failure alters the clearance of most drugs to a degree that is inversely proportional to the glomerular filtration rate. Drugs that are entirely cleared by the liver are administered without renal adjustment. Dose is adjusted by either administerin a percentage of normal dose (d) or increasing the interval (i) between the doses by hours (18–20). The normal loading dose can be administered for virtually all drugs. Unlike hemodialysis, peritoneal dialysis usually has no significant effect on the clearance of most drugs. However, a supplemental dose is sometimes required. Blood levels of drug, if available, are the best guide. PD, peritoneal dialysis; q, every.